U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-289 875

Carbon Monoxide Network Design Methodology - Application in the Las Vegas Valley

Systems Applications, Inc, San Rafael, CA

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, NV

Sep 78

United States
Environmental Protection
Agency

Environmental Monitoring
and Support Laboratory
P.O. Box 15027
Las Vegas NV 89114

EPA-600/4-78-053
September 1978

PB 289875

Research and Development

EPA

Environmental Monitoring Series

Carbon Monoxide Monitoring Network Design Methodology

Application in the Las Vegas Valley

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-78-053

2.

3. RECIPIENT'S ACCESSION NO. PB289875

4. TITLE AND SUBTITLE
CARBON MONOXIDE NETWORK DESIGN METHODOLOGY --
Application in the Las Vegas Valley

5. REPORT DATE September 1978

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) J.L. McElroy, J.V. Behar, L.M. Dunn, P.N. Lem, A.M. Pitchford, N.T. Fisher, M. K. Liu, T. N. Jerskey, J.P. Meyer, J. Ames, G. Lundberg

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Systems Applications, Incorporated
950 Northgate Drive
San Rafael, CA 94903

10. PROGRAM ELEMENT NO. 1HE775

11. CONTRACT/GRANT NO. 68-03-2399

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency-Las Vegas, NV
Office of Research and Development
Environmental Monitoring and Support Laboratory
Las Vegas, NV 89114

13. TYPE OF REPORT AND PERIOD COVERED Final report

14. SPONSORING AGENCY CODE EPA/600/07

15. SUPPLEMENTARY NOTES This report was jointly authored by personnel of Systems Applications, Inc., and EMSL-LV. It is the second in a series (see EPA-600/4-77-019). For further information, contact E.A. Schuck, Project Officer, (702)736-2969, x398, Las Vegas, NV.

16. ABSTRACT

An objective methodology that uses aerometric data and a physically based air quality simulation model was proposed in a previous report for the optimal siting of air pollutant monitoring stations in urban areas. This report describes the continuation of that work--the application of the proposed methodology to the urban Las Vegas area.

The first part of this report contains an examination of the validity of the Atmospheric Pollution Simulation Model, a key component of the proposed methodology. It also describes an intensive field measurement program conducted to provide the necessary data base. The second part describes the selection of meteorological scenarios associated with high pollution potential in the Las Vegas Valley and presents the results of the application of the siting methodology.

One of the principal features of this methodology is the concept of a Figure of Merit for general air quality monitoring. The Figure of Merit represents an average pollutant concentration at each grid point as weighted by the frequency of occurrence of meteorological scenarios.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution	Air monitoring networks	04B
Mathematical models	Air quality monitoring	09B
Systems analysis	Monitoring sites	13B
		14A

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC

19. SECURITY CLASS *(This Report)* UNCLASSIFIED

20. SECURITY CLASS *(This page)* UNCLASSIFIED

21. NO. OF PAGES 149

22. PRICE PCA06

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-600/4-78-053
September 1978

CARBON MONOXIDE MONITORING NETWORK DESIGN METHODOLOGY
Application in the Las Vegas Valley

James L. McElroy, Joseph V. Behar, Leslie M. Dunn,
Pong N. Lem, Ann M. Pitchford, Nancy T. Fisher
Environmental Monitoring and Support Laboratory
Las Vegas, Nevada 89114

and

Mei-Kao Liu, Terry N. Jerskey, James P. Meyer,
Jody Ames, Gary Lundberg
Systems Applications, Incorporated
950 Northgate Drive
San Rafael, California 94903

Contract No. 68-03-2399

Project Officer
Edward A. Schuck
Monitoring Systems Research and Development Division
Environmental Monitoring and Support Laboratory
Las Vegas, Nevada 89114

ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
LAS VEGAS, NEVADA 89114

la

DISCLAIMER

This report has been reviewed by the Environmental Monitoring and Support Laboratory-Las Vegas, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound monitoring data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs.

This report discusses the application of a method for the design of a carbon monoxide monitoring network in the Las Vegas Valley. The procedures for applying the design methodology are given in sufficient detail to guide regional or local pollution control agencies who may have a need to plan new, or modify existing, air quality monitoring networks. The Monitoring Systems Design and Analysis Staff at the EMSL-LV may be contacted for further information on this subject.

George B. Morgan

George B. Morgan
Director
Environmental Monitoring and Support Laboratory
Las Vegas

ABSTRACT

An objective methodology that uses aerometric data and a physically based air quality simulation model was proposed in a previous report for the optimal siting of air pollutant monitoring stations in urban areas. This report describes the continuation of that work--the application of the proposed methodology to the urban Las Vegas area.

The first part of this report contains an examination of the validity of the Atmospheric Pollution Simulation Model, a key component of the proposed methodology. It also describes an intensive field measurement program conducted to provide the necessary data base. The second part describes the selection of meteorological scenarios associated with high pollution potential in the Las Vegas Valley and presents the results of the application of the siting methodology.

One of the principal features of this methodology is the concept of a Figure of Merit for general air quality monitoring. The Figure of Merit represents an average pollutant concentration at each grid point as weighted by the frequency of occurrence of meteorological scenarios.

CONTENTS

Page

Foreword iii
Abstract iv
Figures vi
Tables vii
Abbreviations viii
Acknowledgement ix

I. Introduction 1
II. Summary 2
III. Outline of Siting Methodology 4
IV. Validation of the APSM in the Las Vegas Valley 7
    Objective
    Summary of the APSM
    Field Measurement Program
        Las Vegas Valley
        Historical Information
        Sampling Rationale and Plan
    Simulation Model Input Data
        Modeling Region
        Emissions Inventory for CO
        Aerometric and Other Data
    Comparisons of Predictions and Measurements
    Model Validation Summary and Conclusions
V. Application of Siting Methodology to the Las Vegas Valley 38
    Overview
    Meteorological Scenarios Pertaining to High CO Concentrations
    Exercise of Siting Methodology
    Results and Discussion
VI. Concluding Remarks 50

References 51
Appendices 52

A. Field Program Instrumentation 54
B. Emissions Inventory for the Las Vegas Valley 60
C. Isopleth Maps of Simulation Days 73

FIGURES

Number		Page
1	Plan for demonstrating the siting methodology	5
2	Map of the Las Vegas Valley area	11
3	Carbon monoxide measurement sites	15
4	Meteorological measurement sites	16
5	Weekly variation of the average daily maximum CO at selected stations	18
6	Location of virtual wind stations relative to the actual stations in the modeling grid	21
7	Diagram of predicted vs. measured CO concentration in the Las Vegas Valley on January 21, 1976	25
8	Diagram of predicted vs. measured CO concentration in the Las Vegas Valley on December 3, 1975	26
9	Predicted and measured CO concentrations at selected sites near Las Vegas on December 3, 1975	28
10	Predicted and measured CO concentrations at selected sites near Las Vegas on December 4, 1975	29
11	Predicted and measured CO concentrations at selected sites near Las Vegas on January 14, 1976	30
12	Predicted and measured CO concentrations at selected sites near Las Vegas on January 16, 1976	31
13	Predicted and measured CO concentrations at selected sites near Las Vegas on January 21, 1976	32
14	Predicted and measured CO concentrations at selected sites near Las Vegas on January 22, 1976	33
15	Wind data for 1600 PST, January 16, 1976	34
16	Isopleths of Figures of Merit based on maximum 1-hour average CO concentrations in the Las Vegas Valley	45
17	Locations of CO measurement sites and those proposed on the basis of maximum 1-hour average CO concentrations	46
18	Isopleths of Figures of Merit based on morning 8-hour (0500 to 1200 LST) average CO concentration in the Las Vegas Valley	48
19	Isopleths of Figures of Merit based on evening 8-hour (1200 to 1900 LST) average CO concentration in the Las Vegas Valley	49
A-1	Helicopter spiral sites in the Las Vegas Valley	55
B-1	Emissions inventory grid definition	61
B-2	Relationship between grid systems for data used in the present study	63
C-1 through C-24		74-97

TABLES

Number		Page
1	Data Required as Input to the Model for the Las Vegas Valley Validation Study	12
2	Roughness Parameter for Land-Use Categories in the Las Vegas Valley	23
3	Statistical Comparison of Predicted and Measured CO Concentrations	24
4	Classification of Meteorological Scenarios	41
5	Meteorological Scenarios Selected for the Las Vegas Valley	42
A-1	Data Collecting Sites	57
A-2	Land-Use Characteristics in the Vicinity of the CO Monitoring Sites	58
B-1	Total Carbon Monoxide Emissions (kg/h) for the Las Vegas Valley by Source Type for Constant Reference Temperature of 10°C	70

ABBREVIATIONS

APSM -- atmospheric pollution simulation model
CCHD -- Clark County Health District
CO -- carbon monoxide
DIF -- dual isotope fluorescence
EPA -- U.S. Environmental Protection Agency
h -- hour
HDV -- heavy duty vehicle(s)
kg -- kilogram(s)
km -- kilometer(s)
LDV -- light duty vehicle(s)
LST -- local standard time
LTO -- landing and takeoff
m -- meter(s)
mb -- millibar
m/s -- meters per second
MRI -- Meteorology Research, Incorporated
MSL -- mean sea level
NAAQS -- National Ambient Air Quality Standards
NBS -- National Bureau of Standards
NDH -- Nevada Department of Highways
NLV -- North Las Vegas
NOAA -- National Oceanographic and Atmospheric Administration
NSO -- Nuclear Support Office
NTS -- Nevada Test Site
NWS -- National Weather Service
ppm -- parts per million
s -- second(s)
SAI -- Systems Applications, Incorporated
UNLV -- University of Nevada, Las Vegas
UTM -- Universal Transverse Mercator

NOTE: Certain symbols used in this report bear different connotations or descriptions. These particular symbols, however, are part of an equation, table, or figure and are defined specifically to that usage.

ACKNOWLEDGEMENT

A number of Federal, State, and local governmental agencies provided invaluable assistance in the initiation and execution of this project. The Nuclear Support Office of the National Weather Service in Las Vegas provided meteorological equipment and training; Nellis Air Force Base provided meteorological data and emissions data for the Base; current meteorological data and climatological summaries of the Las Vegas Valley were collected and assembled by the National Weather Service; the General Services Administration provided space for a field measurement station; and the U.S. Environmental Protection Agency's Region IX assembled the initial emissions inventory for the Las Vegas Valley. The Nevada State Department of Highways participated in the field measurement program by providing several instrumented sampling sites and furnished updated data on emissions in the form of traffic summaries. The Air Pollution Control Division of the Clark County Health District (CCHD) provided field data and operated several sampling sites. The Clark County Electrical Division supported the field maintenance of meteorological stations through loan of equipment. The City of Las Vegas and the City of North Las Vegas permitted use of existing streetlight poles as structures for locating meteorological equipment.

The cooperation of a number of private organizations is acknowledged for allowing equipment to be located on their property. These include the: Central Telephone Company, Desert Inn Country Club, KBMI Radio Station, Hughes North Las Vegas Terminal, Rob's Motel, and Sky Harbor Airport.

Private corporations that supplied information pertinent to emissions include Nevada Power Company, Southwest Gas Corporation, Hughes Executive Terminal, Hughes North Las Vegas Terminal, and Union Pacific Railroad.

Key personnel in all the aforementioned organizations were most helpful in providing the very necessary support to the field study conducted in the Las Vegas Valley.

Drs. C. Shepard Burton and Phillip M. Roth of Systems Applications, Incorporated (SAI), provided many helpful comments on this work.

I INTRODUCTION

The monitoring of ambient air quality is an indispensable element of air pollution studies. Field measurements, if gathered in an adequate manner, probably provide the most valuable information on a number of environmental issues, such as the identification of air pollutants of concern, the determination of their concentrations, and the search for their concentration patterns and trends (Morgan et al., 1970). It is, therefore, not surprising that the Clean Air Act, as amended in 1970, required ambient air monitoring programs as part of the State Implementation Plans.

The establishment of a monitoring network is costly. Since air pollution in an urban area is the end product of many complicated circumstances and events with noticeable spatial and temporal variability, pollutant concentrations generally vary significantly in time and space. Thus, the selection of monitoring sites is one of the most crucial problems in the design of an air quality monitoring network. Designing a network that fulfills its intended goal at the lowest cost (i.e., with the fewest monitors) is a complex and difficult task. Until very recently, however, this problem had not been fully addressed. The selection of monitoring sites was usually based on either subjective judgment or nontechnical considerations such as convenience and accessibility.

The first in this series of reports (Liu et al., 1977) discussed various aspects of concern in the siting of air quality monitors, and proposed a methodology for a rational design of a network for carbon monoxide (CO). Conceptually, the methodology presented is generally valid for any airborne pollutant. Carbon monoxide was chosen because it is a relatively inert pollutant for which the methodology should be presentable in its basic, simplest form.

This report describes the application of the siting methodology to the Las Vegas Valley area of Nevada. A brief review of the methodology is included from the theory detailed in the previous report to make this document complete in itself. The validity of a mesoscale air quality simulation model, a key component of the proposed methodology, is tested using field data collected in the Las Vegas Valley. The actual application of the siting methodology is then described. Proposed changes or additions to the methodology to increase its versatility are also discussed.

II SUMMARY

This report details the application of the specific siting methodology for CO to the Las Vegas Valley area of Nevada. Demonstration of the proposed approach consists of two major tasks. First, the establishment of the validity of the air quality simulation model selected for this study. The second major task consists of several subtasks:

- Examination of climatological information in order to characterize meteorological patterns potentially leading to high pollutant concentrations. This includes calculation of the frequency of occurrence of such patterns.

- Exercise of the air quality simulation model for each of the meteorological patterns identified to generate the corresponding pollutant distribution pattern.

- Selection of monitoring sites based on these pollutant distribution patterns and predetermined selection criteria (in the present case, those sites most representative of local maximum concentrations).

Utilizing data gathered in the field measurement program, the air pollution simulation model was exercised for 6 days during the winter of 1975-1976. The predictions for these 6 days were compared with field measurements in order to assess the validity of the model. Spatial and temporal distributions of pollutant concentrations as well as point-by-point comparisons of predictions and measurements were considered in judging the validity of model predictions.

The model predicted diurnal trends well but often failed to predict the absolute values of peak concentrations especially in the downtown and Las Vegas Wash areas. These locations are where the highest value afternoon traffic peak is experienced (downtown) and at the lowest point (topographically) in the Valley (Las Vegas Wash). The weakness in the predictions for these areas implies unresolved microscale effects. Diagrams of comparison data show a tendency to underpredict at high CO values but most of the correlation coefficients were acceptable for hourly comparisons (in the range of 0.7 to 0.9).

One further observation on the model's behavior was in showing CO stations to be located where a strong gradient of predicted CO concentrations often occurred. This suggests that slight uncertainties in the wind field specification could greatly affect the comparisons.

Limited sensitivity analysis in this study and those conducted by others including parametric analysis stress the influence of wind field and emissions uncertainties and unresolved microscale effects on the results. These difficulties can be resolved and are part of ongoing research.

In this study, the desirability of placing an air quality monitor at a given location is measured by a Figure of Merit. This measure is defined as the product of an air quality index at a particular location and the associated frequency or probability of occurrence of prevailing (or specified) meteorological conditions at that location. Development of the meteorological scenarios can be effected using different objective analysis techniques, depending on the availability of data. In this exercise, the scenarios were developed directly from atmospheric mixing depth and wind speed data for the dates experiencing the lowest 20 percent of atmospheric ventilation rates. For this purpose, a two-way contingency table involving atmospheric mixing depth and wind speed was devised using this subset of the 5-year data set for the local CO season. These data were further grouped according to wind speed alone. Existing wind field data collected during an intensive measurement date provided the balance of the information for the meteorological scenarios as employed in the air quality simulation model. The predicted hour-by-hour CO concentrations for each grid point were then used as indices to compute Figures of Merit. Isolated high values of the Figure of Merit were ranked to select potential monitoring locations.

A different set of Figures of Merit was calculated based on 8-hour averages of CO concentrations for the morning and evening periods. These periods were 8-hour averages centered around the morning and afternoon peak traffic hours, respectively. The locations of the highest nine values for each set of 8-hour averages and the worst 1-hour average indicated that the expected high values of CO concentrations do vary in location during the day. The selection of the particular locations for monitoring suggested by the Figures of Merit depends, therefore, on which emission patterns are most desirable to be measured.

Current research is centered on incorporating a procedure for selecting the number of sites in the design methodology in terms of either cost/benefit for a unit of monitoring information or acceptable error concepts.

III OUTLINE OF SITING METHODOLOGY

The design of an air quality monitoring network involves a number of multidiscipline considerations, ranging from policy decisions on the need and cost of the network to technical decisions on the selection of sites, the choice of measuring instruments, and the operation and maintenance of the network. The present project is concerned with the most crucial step in the design of an air quality monitoring network--the actual siting of the measurement stations.

Rational design procedures for selecting sampling sites cannot be formulated without a set of well-defined goals or objectives for the monitoring program. After they are determined, a number of criteria for evaluating the relative merits of different network configurations can then be clearly stated. For example, if the objective of the proposed monitoring program is to detect the long-term trends of air pollution, the proper criterion for site selection is that the pollutant concentrations at the chosen sites be most sensitive to changes in source emission strengths. If the objective as described herein is to assess whether existing concentrations exceed an air quality standard, the sites should be chosen so that the measurements are most representative of the local maximum concentrations. These monitoring goals not only lead to different selection criteria but, also, affect the nature of siting methodology to be used. In some cases, a rigorous mathematical optimization technique can be implemented to obtain the best results (e.g., Seinfeld, 1972; Darby et al., 1974); in other cases, a set of simple heuristic decision rules may be the appropriate tool.

It is well known that pollutant concentrations are highly variable in both time and space. The concentrations at a given receptor site are a function of both emissions (locations, strengths, temporal variations, etc.) and atmospheric conditions (wind distribution, turbulent diffusion, vertical temperature structure, etc.). The optimal placement of monitoring sites requires a priori knowledge about the pollutant distributions under a variety of conditions. Therefore, the key component in any logical siting methodology is a predictive scheme, such as an air quality model, that links emissions from sources with the observed air quality (Behar et al., 1976).

Through active research and development in the last decade, many air quality models have been developed that are applicable to both inert and photochemical air pollutants in urban areas. They range from simple approaches such as the nonlinear rollback model (Schuck and Papetti, 1973) to complex numerical models such as the Atmospheric Pollution Simulation Model (APSM)*

---

*Also known as Atmospheric Pollution Simulation Program (APSP).

(Reynolds et al., 1973, 1974; Roth et al., 1974). These models can provide valuable assistance in the design of air quality monitoring networks.

An earlier report (Liu et al., 1977) described the approach for the selection of optimal monitoring sites. As shown in Figure 1, a demonstration of the approach proposed consists of two tasks. The first is an examination of the validity of the air quality model. The purpose of this task is to assess the ability of the air quality model employed to reproduce the pollutant concentration distributions.

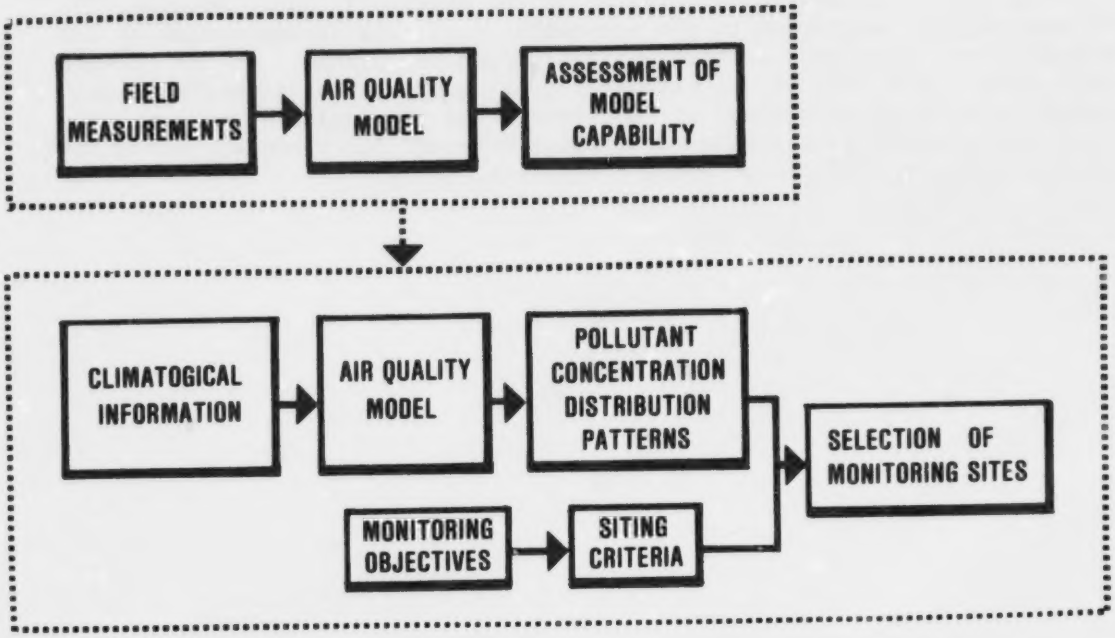

FIELD MEASUREMENTS
AIR QUALITY MODEL
ASSESSMENT OF MODEL CAPABILITY
CLIMATOGICAL INFORMATION
AIR QUALITY MODEL
POLLUTANT CONCENTRATION DISTRIBUTION PATTERNS
SELECTION OF MONITORING SITES
MONITORING OBJECTIVES
SITING CRITERIA

Figure 1. Plan for demonstrating the siting methodology

The APSM mentioned earlier was selected for the present project primarily because it can provide spatial distributions for reactive pollutants. After the validity of the model is established, the second task can then be carried out in the following steps:

- Characterization of meteorological patterns that potentially lead to high air pollutant concentrations. This involves the use of historical records including climatological information for the region of interest.

- Utilization of the air quality model for each of the meteorological patterns to generate the corresponding pollutant distribution patterns.

- Selection of monitoring sites based on these pollutant distribution patterns and predetermined selection criteria.

The above tasks were carried out for the Las Vegas Valley area of Nevada. The Las Vegas Valley was selected because it is an isolated urban area where it is expected that very little pollutant of interest would enter the modeling region from other areas, and thus, boundary conditions could easily be determined. Furthermore, complex and costly logistical support was not required because the field program was directed from the EPA's Environmental Monitoring and Support Laboratory located in the valley.

The results presented are limited to the chemically inert species, CO, and analysis is restricted to the mesoscale; i.e., the determination of the general areas where the monitoring sites should be located. In the present application, this area is a 1-kilometer (km) square. The extension of the present work to photochemical air pollutants and the inclusion of a microscale analysis for pinpointing the optimal location for a monitor within each general area are subjects of current research.

IV VALIDATION OF THE APSM IN THE LAS VEGAS VALLEY

One of the key components of the siting methodology is an air quality simulation model that relates local emissions to ambient air quality. In the present project, a 3-dimensional photochemical model (the APSM) was selected for mesoscale analysis. The APSM was originally developed for use in the Los Angeles, California, metropolitan area. As such, it contained some components applicable only to that area. Consequently, as a first step in the project, the APSM was modified by removing these site-specific components and replacing them with ones considered more general in nature. The modifications are described in Liu et al. (1977), Ames et al. (1978), and later in this chapter.

The usefulness of the siting methodology depends upon the relative accuracy with which the APSM predicts ground-level concentration distributions. Therefore, a model validation study was included as part of this project. This undertaking included a comprehensive field measurement program conducted in the Las Vegas Valley as the urban area chosen for development of the siting methodology. Using the data collected in the field measurement program, the APSM was exercised for 6 days and its predictions were compared with measurements. A detailed description of this effort follows.

OBJECTIVE

The objective of a model validation study is to assess the ability of the model to achieve the best possible comparison between model predictions and measurements, given the limitations of the input aerometric and measured air quality data. The accuracy of the model predictions depends on

- the adequacy of the model formulation and solution procedures
- the availability and accuracy of data required as input.

Because the quantity of input data which the APSM requires is not always available, the modeler may have to make some assumptions or estimates about the input data that are not available. Some uncertainty is introduced by this procedure, and the modeler has the prerogative of adjusting his estimates within the limits of physical reality. These limits are determined by the range of values normally observed or the values of the input data that are available. Methods of obtaining the required input from limited data range from simple interpolation to complex solutions of the momentum and energy equations for the atmosphere. The latter often require other data to obtain a solution. The method chosen depends on the resources at the disposal of the modeler and the data available.

Differences between model predictions and measurements depend not only on model accuracy but also on the accuracy and representativeness of the measurements that are compared with the predictions. Representativeness in this context refers to how well the data represent the conditions to which the model predictions apply. Representativeness is of particular importance in this project because the concentrations predicted by the APSM are spatially averaged over an area of 1 square kilometer.

This horizontal grid size was considered to be the smallest one consistent with the computational requirements and capabilities of the particular computer utilized, the areal extent of the modeling region, and the resolution of the pollutant emissions data.

It is important that monitoring sites not be located in the immediate vicinity of sources in order that the measured concentrations be representative of the chosen spatial area. If there is reason to believe that data from a particular site are not representative of the spatial average in the area or, if there is some reason to suspect their accuracy, the data should not be used for model validation.

Models need to be validated in a manner consistent with their intended use (Simmons, 1974). Herein, the concern is with concentrations which exceed ambient air quality standards. Thus, meteorological conditions conducive to high pollutant concentrations were desired. The validation dates were chosen with this general goal in mind.

There is no simple or single proven measure that can be used to judge the overall goodness of an air quality simulation model (Olsson and Ring, 1974). Usually, a combination of graphical and statistical measures is used for this purpose. In the present project the ability of the APSM to locate "hot spots" or maxima in concentrations in reproducing a data base for the site-selection process requires assessment.

Thus both the spatial and temporal distributions of concentrations are considered in judging the validity of model predictions. Point-by-point comparison of predictions and measurements is made. Also, the predictions and measurements are examined collectively and comparison of concentration distributions are made in addition to those on an individual basis.

SUMMARY OF THE APSM

The theoretical framework of the APSM is described in detail in the previous report (Liu et al., 1977) and in the previously cited references. The formulation of the APSM for the present application is given by equation 1. A transformation of coordinates was performed on the usual mass continuity equation with the assumption that the slope of the land and the inversion layer are negligible over the modeling region. This transformation aids in the computational stability of the numerical solution to this equation.

$$\frac{\partial}{\partial\tau}(\Delta H c_i) + \frac{\partial}{\partial\xi}(u\Delta H c_i) + \frac{\partial}{\partial\eta}(v\Delta H c_i) + \frac{\partial}{\partial\rho}(W c_i) = \frac{\partial}{\partial\xi}\left(K_H\Delta H\frac{\partial c_i}{\partial\xi}\right) + \frac{\partial}{\partial\eta}\left(K_H\Delta H\frac{\partial c_i}{\partial\eta}\right) + \frac{\partial}{\partial\rho}\left(\frac{K_V}{\Delta H}\frac{\partial c_i}{\partial\rho}\right) + S_i\Delta H\ , \tag{1}$$

c_i = concentration of the i-th species,

τ = time coordinate,

ξ,η = horizontal cartesian spatial coordinates,

ρ = vertical spatial coordinate = $\dfrac{z - h(x,y)}{H(x,y,t) - h(x,y)}$,

z = height above mean sea level,

$\Delta H = H(x,y,t) - h(x,y)$,

$H(x,y,t)$ = height of the elevated stable layer above mean sea level,

$h(x,y)$ = height of the ground above mean sea level,

u,v,w = wind velocity components in the ξ,η, and ρ directions,

$$W = w - u\left(\frac{\partial h}{\partial\xi} + \rho\frac{\partial\Delta H}{\partial\xi}\right) - v\left(\frac{\partial h}{\partial\eta} + \rho\frac{\partial\Delta H}{\partial\eta}\right) - \rho\frac{\partial\Delta H}{\partial\tau}\ ,$$

K_H = horizontal eddy diffusivity,

K_V = vertical eddy diffusivity.

S_i = rate of emission of species i from sources located between H and h. Terms in the generalized equation involving chemical reactions and removal mechanisms have been eliminated for the present application to CO. The solution of equation (1) requires as input, the wind field (from measurements or a predictive scheme), height of the elevated stable layer, and the vertical and horizontal eddy diffusivities over the entire region and time to be simulated. Additional input data are required as a result of the boundary conditions (Reynolds et al., 1973):

$$\rho = 0 \qquad Q_i(\xi,\eta,\tau) = -\frac{K_V}{\Delta H}\frac{\partial c_i}{\partial\rho}\ , \tag{2}$$

$$\rho = 1 \qquad \left.\begin{array}{ll} Wc_i - \dfrac{K_V}{\Delta H}\dfrac{\partial c_i}{\partial\rho} = Wg_i(\xi,\eta,1,\tau) & \text{if } W \le 0 \\ -\dfrac{K_V}{\Delta H}\dfrac{\partial c_i}{\partial\rho} = 0 & \text{if } W > 0 \end{array}\right\}\ , \tag{3}$$

$$\xi = \xi_W \text{ or } \xi_E \quad \left.\begin{array}{ll} uc_i - K_H \dfrac{\partial c_i}{\partial \xi} = ug_i & \text{if } \vec{U}\cdot\vec{\eta} \le 0 \\ - K_H \dfrac{\partial c_i}{\partial \xi} = 0 & \text{if } \vec{U}\cdot\vec{\eta} > 0 \end{array}\right\} , \qquad (4)$$

$$\eta = \eta_S \text{ or } \eta_N \quad \left.\begin{array}{ll} vc_i - K_H \dfrac{\partial c_i}{\partial \eta} = vg_i & \text{if } \vec{U}\cdot\vec{\eta} \le 0 \\ - K_H \dfrac{\partial c_i}{\partial \eta} = 0 & \text{if } \vec{U}\cdot\vec{\eta} > 0 \end{array}\right\} , \qquad (5)$$

where

Q_i = the mass flux of species i at the surface,
$\vec{U}$ = $u\hat{i} + v\hat{j}$,
$\hat{i}$ = unit vector in the ε direction,
$\hat{j}$ = unit vector in the η direction,
$\vec{\eta}$ = the outwardly directed unit vector normal to the horizontal boundary,
g_i = the mean concentration of species i just outside the modeling region.

Thus, the data requirements as a result of the boundary conditions are the pollutant concentrations at both the sides and the top of the modeling region and the flux of emissions into the bottom of the modeling region. The data required as input to the APSM are summarized in Table 1.

FIELD MEASUREMENT PROGRAM

Data for the model validation effort were acquired through a field measurement program. In the Las Vegas Valley, existing data collection activities were reviewed and historical information examined to determine the need for supplemental measurement sites. The availability of historical information and the extent of current monitoring activities influenced the selection of meteorological and air quality monitoring sites.

Las Vegas Valley

The Las Vegas Valley represents a relatively isolated but mostly urbanized area. It contains a desert community with a population of over 300,000. The valley, located in Clark County in southern Nevada, is bounded by the Sheep Range and Las Vegas Range to the north, the Spring Mountains to the west, Frenchman and Sunrise Mountains to the east, and the McCullough Range to the south (Figure 2). These mountains, averaging about a kilometer above the valley floor, impart a bowl shape to the valley with relief passes

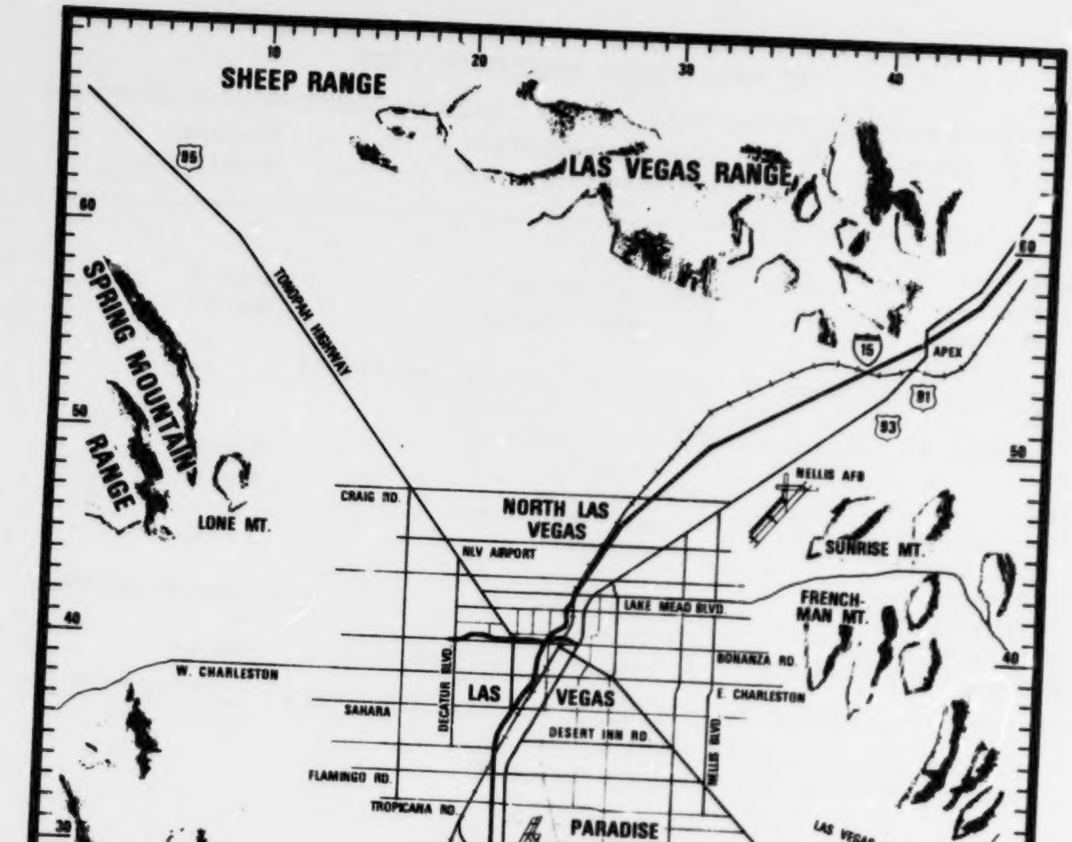

SHEEP RANGE
LAS VEGAS RANGE
SPRING MOUNTAIN RANGE
LONE MT.
TONOPAH HIGHWAY
95
15
93
91
APEX
NELLIS AFB
SUNRISE MT.
FRENCHMAN MT.
CRAIG RD.
NORTH LAS VEGAS
NLV AIRPORT
LAKE MEAD BLVD.
BONANZA RD.
W. CHARLESTON
E. CHARLESTON
DECATUR BLVD.
LAS VEGAS
SAHARA
DESERT INN RD.
NELLIS BLVD.
FLAMINGO RD.
TROPICANA RD.
PARADISE
MC CARRAN AIRPORT
LAS VEGAS WASH
BOULDER HWY.
UNION PACIFIC R.R.
SUNSET ROAD
INDUSTRIAL AREA
BLUE DIAMOND
LAS VEGAS BLVD.
HENDERSON
HENDERSON CUTOFF
ARDEN
SKY HARBOR AIRPORT
BIRD SPRING RANGE
SLOAN
91
MC CULLOUGH RANGE
15
466
1 2 3 4 5 6 7 8
KILOMETERS
N
10
20
30
40
60
50
40
30
20
10

Figure 2. Map of the Las Vegas Valley area

TABLE 1. DATA REQUIRED AS INPUT TO THE MODEL FOR THE LAS VEGAS VALLEY VALIDATION STUDY

Data Required	Spatial Resolution and Characteristics	Temporal Resolution
Emissions		
Surface	Surface cells*	Hourly
Elevated	Specified cells*	Hourly
Air quality		
Initial conditions	All cells (assumed vertically invariant)	
Boundary conditions	Top and upward side boundary cells	Hourly
Winds	All cells	Hourly
Elevated stable layer heights	Assumed spatially invariant	Hourly
Horizontal eddy diffusivity	Assumed constant	Assumed constant
Surface roughness†	Surface cells	--
Atmospheric stability†	Assumed spatially invariant	Hourly

* "Cells" in Table 1 are all 1 km by 1 km.

† Required for vertical eddy diffusivity.

to the northwest, southwest and southeast. The floor of the valley slopes gently from west to east about 980 meters (m) mean sea level (MSL) on the west to about 550 m MSL on the east-southeast side. To the east of the Las Vegas Wash, the terrain gently rises again.

The main economic base of tourism is supplemented by a substantial trucking and warehousing industry, a large mineral and metal mining and refining industry, and the operations of several large governmental organizations. Because the urban area of Las Vegas consists of vacant desert scattered among residential developments, the population is distributed over a larger area than many other urban communities of equivalent population. To serve this large area, a limited access interstate highway traverses the city and major highways crisscross the valley providing access from Arizona to northwestern Nevada, and from California to Utah. A large grid of four- and six-lane arterial streets and an intermeshed network of secondary roadways accommodate local traffic in the valley.

Historical Information

To plan the initial measurement program, a survey of available information was conducted. Several Federal and State agencies have ongoing data collection efforts in the Las Vegas Valley, in both meteorology and air quality.

Meteorological data are collected locally by the National Weather Service (NWS) at McCarran International Airport and at the Nevada Test Site (NTS) and by the U.S. Air Force at Nellis Air Force Base (see Figure 2). The NTS is about 100 km north of Las Vegas. Near-surface weather information including that on cloud cover, visibility, barometric pressure, air temperature and moisture, precipitation, and wind speed and direction are provided at 1-hour intervals at the airport location. Upper air data on temperature, moisture, and wind speed and direction are collected at the NTS. Vertical soundings of these parameters are made at 0400 and 1600 local standard time (LST). Prior to 1966 the soundings were taken at McCarran International Airport. Data from these and other sources are compiled at the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Center in Asheville, North Carolina. In addition, the NWS operates a local Nuclear Support Office (NSO), including coverage of the NTS, for the Department of Energy with weather forecasting capabilities and a library of publications pertinent to southern Nevada. Much of the meteorological equipment used in the field program was on on loan from the NSO under a cooperative agreement.

Aerometric data beginning in the fall of 1974 are available from the State of Nevada Department of Highways (NDH), which operates two trailers in the Las Vegas area equipped to monitor air quality and wind speed and direction. The Clark County District Health Department (CCHD) operates four air quality measurement sites locally (data archived beginning in 1974). Arrangements to share current and historical data were made with both agencies.

Sampling Rationale and Plan

Historical data indicated that CO, total suspended particulates, and oxidants were the major criteria pollutants of concern in the valley. Because CO is relatively inert, this pollutant was chosen as the simpler case to test the methodology for the design of an optimum monitoring network.

The period for full scale aerometric sampling for both the routine and intensive programs was chosen as November 1975 through February 1976, inclusive. Limited historical CO data collected by the CCHD indicate that the highest daily and shorter term concentrations and frequency of exceeding the National Ambient Air Quality Standards (NAAQS) for CO all occur during this period of the year. Historical weather data for the Las Vegas Valley show that the meteorological conditions conducive to high concentrations of CO also occur most frequently during this period of the year.

Climatologically, the period of minimum dilution in the Las Vegas Valley for pollutants such as CO, which are emitted primarily from near-ground-level sources, is that of late fall and early winter. Both the atmospheric mixing depth (Holzworth, 1964) and the average wind speed through the depth (Holzworth, 1962) are generally smallest during this time of the year. Thus, the dilution or ventilation rate, which is comprised of the product of these parameters, follows a similar pattern. The meteorological potential for air pollution episodes is also highest then. Holzworth (1974), for example, observed that the episode of slowest dilution and the episode of longest duration for a 5-year data sample both occurred locally in December. An episode in this analysis was defined as a period of 5 or more consecutive days of high meteorological air pollution potential, with the potential being determined in terms of mixing depth, wind speed through the depth, and the details of the dominant synoptic scale weather features.

As was discussed in the previous report (Liu et al., 1977), the Las Vegas Valley is situated in semi-arid terrain and experiences a desert-type climate. This is typified by clear skies, a large diurnal near-surface temperature change, and a strong nocturnal surface-based temperature inversion, especially during times experiencing light wind speeds. Periods of minimal pollutant dispersal are associated with the occurrence of the nocturnal inversion which dissipates most slowly during the first few hours after sunrise and forms around sunset. As shown elsewhere in this report, motor vehicles generate nearly all the emissions of CO. The times of peak activity are 0630-0830 and 1600-1800 LST. Thus, the times of peak emission coincide closely with diurnal segments of minimum pollutant dispersal during the selected sampling period, particularly since sunrise occurs later and sunset earlier than during the rest of the year (see Liu et al., 1977). Consequently, highest short-term concentrations (on the order of a few hours) can also be expected to occur more frequently during this period.

Near-surface sites for routine continuous monitoring of aerometric variables were chosen subjectively on the basis of predominant synoptic scale and locally induced wind patterns (e.g., upslope and downslope winds), topography, land use, and road traffic information. Because of cooperative arrangements with local agencies monitoring in the valley, only new sites required to supplement those existing were maintained by the U.S. Environmental Protection Agency (EPA). Measurements of CO were made at nine stations (Figure 3). Those of wind speed and direction and air temperature were made at 13 sites and of air temperature alone at another four sites (Figure 4). A special effort was made to locate CO monitoring sites away from the immediate vicinity of major emission sources such as roadways.

Special additional sampling of aerometric parameters was accomplished in intensive periods. During these periods, air temperature, moisture, and pollutant data in the vertical were collected with an instrumented helicopter, and measurements of winds aloft were made. The periods began an hour before sunrise and normally continued until 2 to 3 hours after sunset. This time frame was chosen in order to cover both the morning and evening peak emission periods of CO.

Periods for short-term intensive sampling were chosen on the basis of forecasts of synoptic scale weather patterns over the Las Vegas Valley. Days with particularly limited atmospheric dilution were desired. Such situations generally occur when the valley is under the direct influence of a stagnant or slowly moving high pressure area. Weekends were not considered because an adequate CO emissions inventory could not be established for this period from available data.

To insure that this constraint did not invalidate the monitoring systems design, average daily maximum CO concentrations for several years of record

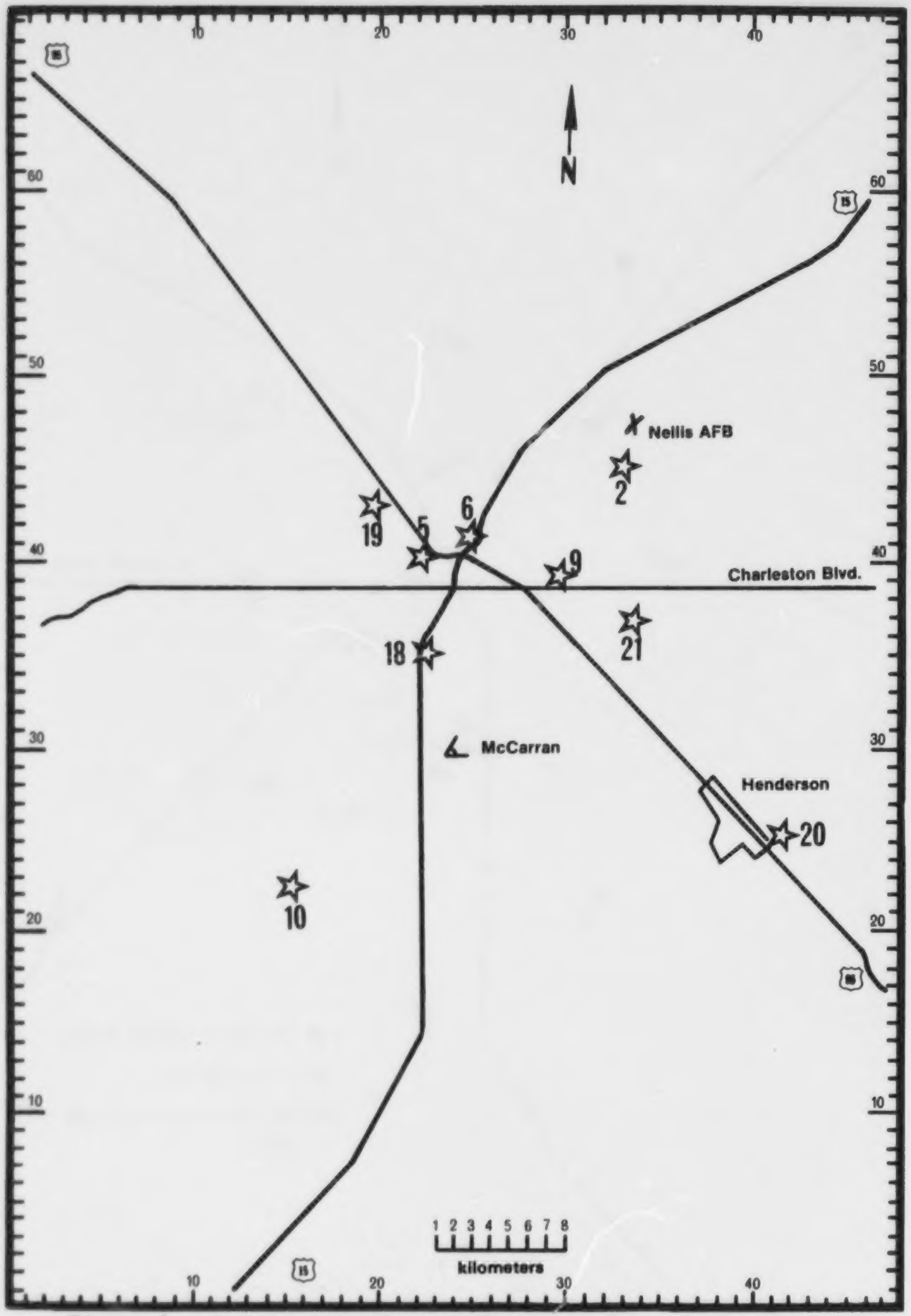

N
Nellis AFB
Charleston Blvd.
McCarran
Henderson
2
5
6
9
10
18
19
20
21
15
10
20
30
40
50
60
1 2 3 4 5 6 7 8
kilometers

Figure 3. Carbon monoxide measurement sites

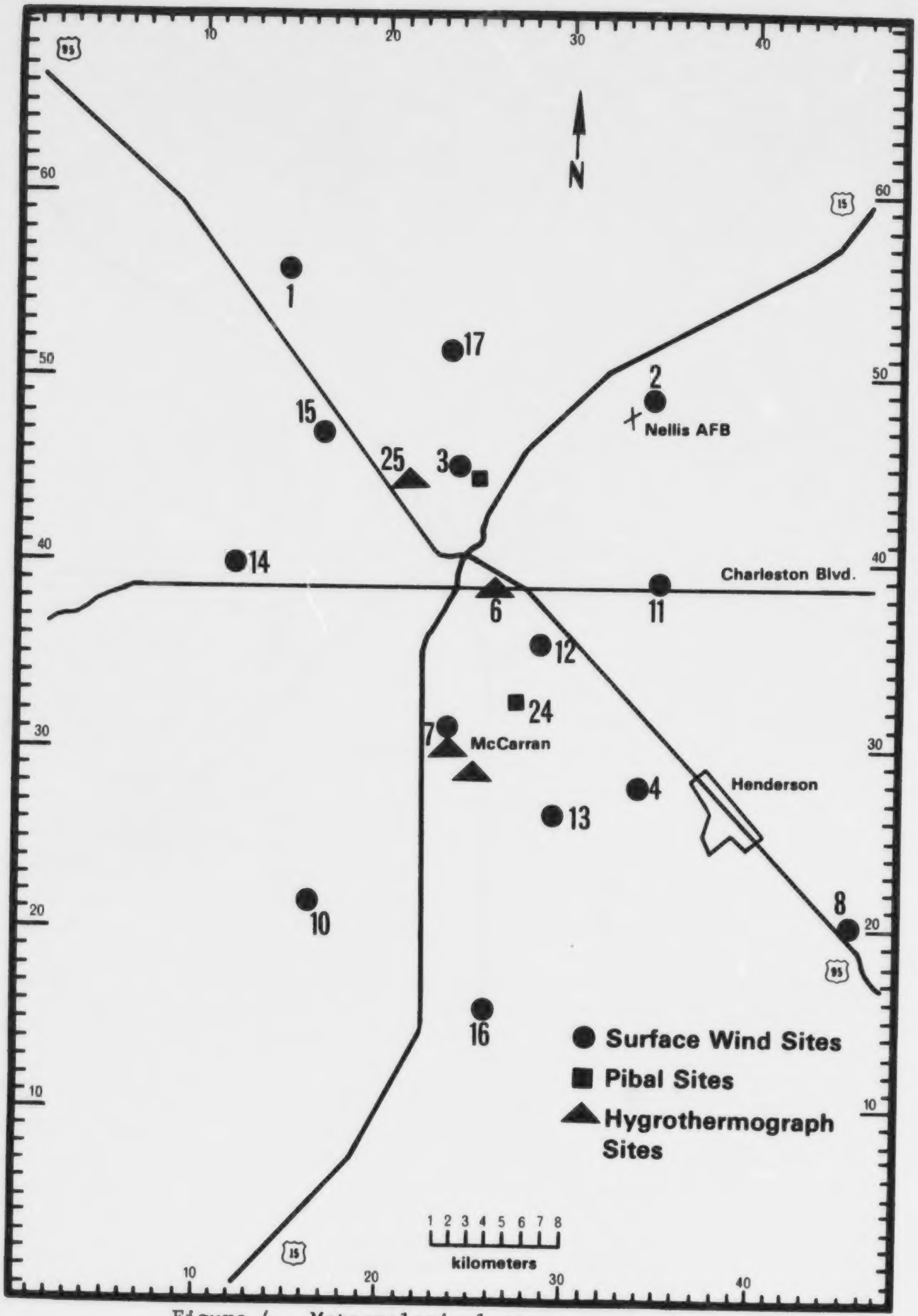

N
95
15
10
20
30
40
60
50
1
17
2
Nellis AFB
15
25
3
14
Charleston Blvd.
6
11
12
24
7
McCarran
4
Henderson
13
10
8
16
● Surface Wind Sites
■ Pibal Sites
▲ Hygrothermograph Sites
1 2 3 4 5 6 7 8
kilometers

Figure 4. Meteorological measurement sites

were plotted. Figure 5 shows these data as a function of day of the week. The plots at these three central city locations generally show slightly higher values during weekdays than during weekends. This fact indicates that the monitoring systems design is not unduly constrained by the absence of weekend emissions data.

Weather forecasts for intensive sampling were made using facilities available at NWS's NSO in Las Vegas where observed surface and upper air data for the contiguous United States are routinely collected by teletype. Facsimile charts containing observed or forecast weather data for ground-level and various constant-pressure surfaces in the atmosphere are received which cover the United States plus portions of adjacent oceans. In addition, special forecast information is available, generally resulting from simulations with synoptic scale meteorological models.

Specific forecasts of weather events for the local area were normally made for periods up to only 24 hours in advance as they could usually be expected to provide reasonably accurate information on the details and timing of such events. As a result, only 1 day of notice was usually provided for intensive sampling periods. Extended weather outlooks during favorable sampling situations for periods up to 48 and 72 hours in advance were also prepared when appropriate. On the basis of such outlooks, field personnel were placed on standby status.

Details of instrumentation used during routine and intensive sampling, including data collection and reduction and quality assurance procedures established for the field measurement program, are contained in Appendix A. Numeration of the sites shown in Figures 3 and 4 is established in Table A-1 of this Appendix.

SIMULATION MODEL INPUT DATA

Modeling Region

As discussed earlier, the Las Vegas Valley represents a relatively isolated urbanized area. It was assumed that boundary conditions could be determined more easily because of this relative isolation. That is, one could reasonably expect that very little pollutant of interest would enter the modeling region from other areas. Consequently, the modeling region was defined as a 48-km by 70-km area extending to the ridgelines surrounding the Valley. The region was divided into 1-km by 1-km squares commensurate with the resolution of pollutant emission data and of the APSM.

It is recognized that the scale of natural variability of CO in the immediate vicinity of major emission sources like roadways is of the order of tens of meters. Microscale considerations should be applied to ensure compatibility between this scale and the resolution of the APSM. However, it was decided to use the results of model simulations unmodified by microscale effects for the purpose of demonstrating the basic utility of the design methodology. It should be noted, as discussed earlier, that detailed CO emission data on a scale less than a 1-km by 1-km square were not available locally and that an effort was made to avoid locating CO monitoring sites in

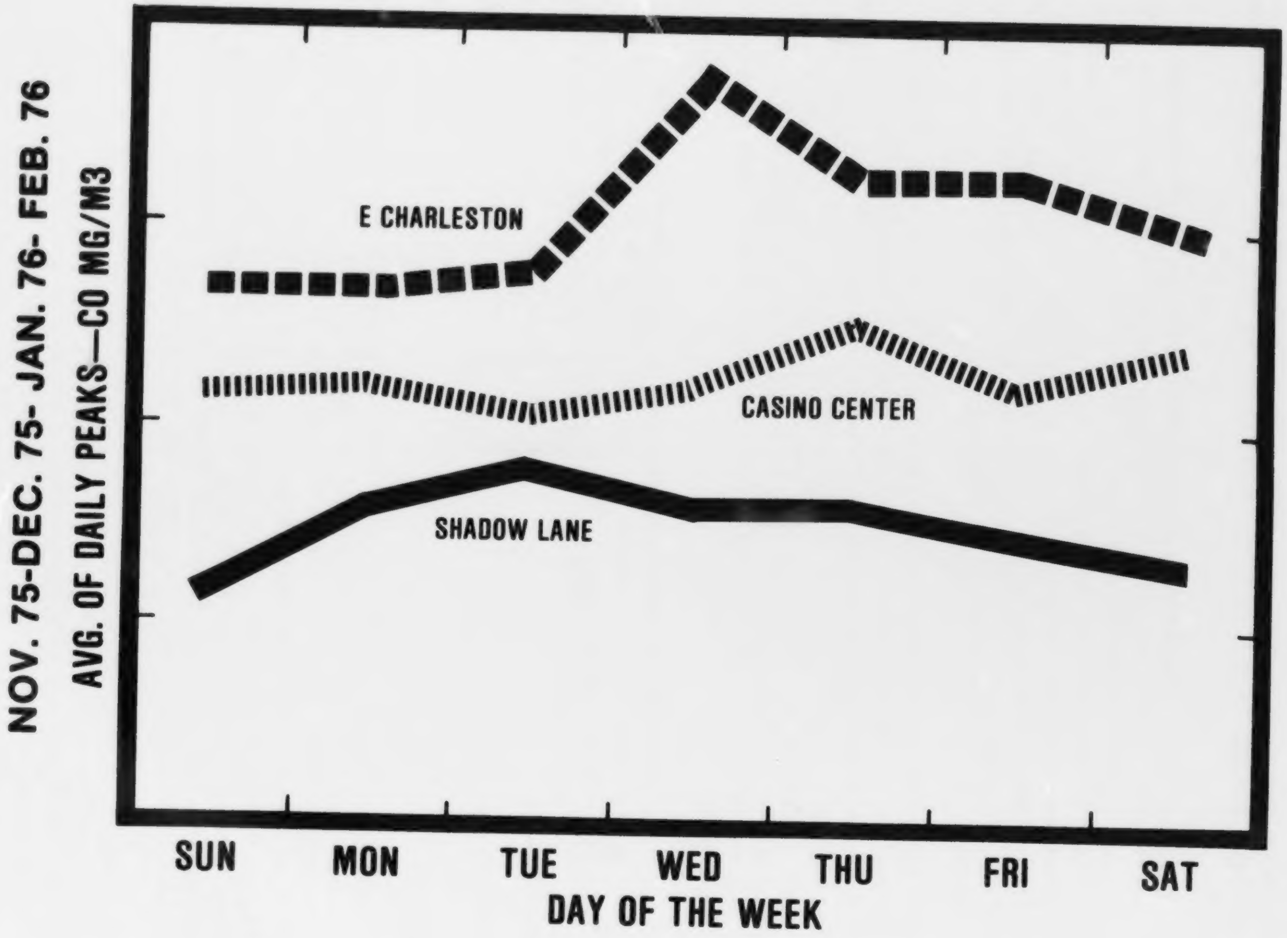


Figure 5. Weekly variation of the average daily maximum CO at selected stations

close proximity to major sources.

Emissions Inventory for CO

Emissions data were inventoried within the modeling region as divided into 1-km by 1-km squares. Emissions from point sources (electric power generation plants and industrial plants), area sources (space heating), and mobile sources (railroads, aircraft, and road vehicles) were determined for each hour of the day within each such grid square. Light duty vehicle (LDV) emissions have been shown to depend on ambient temperatures. These emissions account for 80 percent of the total inventory on a daily basis and must be adjusted to reflect different ambient temperature conditions. Thus, an emissions inventory was developed specifically for each day simulated.

The emissions inventory was developed from information provided by the CCHD, NDH, local industries and utilities, the National Environmental Data System (NEDS) data bank using AP-42 (EPA, 1976) as a guide. Details of methodology including procedures and equations are described in Appendix B.

Aerometric and Other Data

Preparation and use of available aerometric data and other data required as input to the APSM for the Las Vegas validation study are discussed later.

Air Quality Data

Carbon monoxide measurements made at nine sites were previously shown with respect to the modeling grid in Figure 3. This figure illustrates that most of the monitoring sites are located near the center of the modeling region. As a result, there is a high density of data available for validating the model near the center of the region and very little or no data available on the periphery. This situation would ordinarily make it difficult to specify the initial and boundary conditions. However, because of the almost total absence of sources outside the region containing the majority of the stations, it can reasonably be assumed that the initial concentrations in the unmonitored region approach the background levels at large distances from the monitoring sites. Furthermore, the concentrations on the boundaries of the modeling grid can also be safety assumed to be at the background levels. No measurements aloft were available but, based on our knowledge of the vertical distribution of CO at other locales, we assumed that concentrations entrained as the nocturnal inversion rises are also at background levels.

The measurements collected at the monitoring sites are needed to specify the initial pollutant distribution. In order to provide concentrations at each grid point, interpolation is necessary. A two-step procedure was used in this study. First, an automated scheme based on the reciprocal-of-the-distance rule (Liu et al., 1973) was applied using the measured CO data. The resultant CO concentration fields were subsequently smoothed manually. This latter procedure was used because unrealistically high fluctuations in CO concentrations were obtained during early hours of simulations with only the automated technique.

Surface Wind Speed and Direction

Information on the 3-dimensional wind field for each of the grid cells in the modeling region is required at hourly intervals. The computer algorithm described in Chapter III-A of the previous report (Liu et al., 1977) provides these data from the values of horizontal wind speed and direction reported for the grid locations of each of the 13 near-surface wind stations in the Las Vegas field network.

The objective interpolation scheme to develop the near-surface horizontal wind field was modified slightly in order to facilitate application of the algorithm for the local area. The existing wind stations shown with respect to the modeling grid in Figure 6 are grouped together in the central portion of the modeling region, i.e., away from severe terrain. As a result, unrealistic irregular features in the near-surface wind field were often noted near the boundaries when the objective analysis scheme was applied to the Las Vegas data. Through experimentation, it was found that a wind field that retained the basic features of the depicted wind patterns and that eliminated these irregularities could be obtained when nine virtual stations on the periphery of the modeling region were added to the existing data set. A virtual station is not a real measuring site,but a location near the periphery of the modeling region where a value of the wind velocity vector is assigned by vector addition of the velocity vectors of its two nearest actual measuring stations. Specifically, virtual stations were first added to the corners and then to the central portions of the grid edges until the continued addition of stations provided no apparent improvement in smoothness to the wind field near the periphery. These stations are also shown in Figure 6 relative to the existing stations in the modeling grid.

Mixing Depth

The thickness of the atmospheric mixing layer, or mixing depth, at hourly intervals was obtained through analysis of vertical temperature profiles obtained during the helicopter spirals. Wherever possible, data collected by temperature sensors located at the fixed near-surface stations were used to provide ground truth for the helicopter temperature profiles. Additionally, shear information from winds-aloft measurements were used where applicable to assist in establishing the thickness of the mixing layer; often a large shear of horizontal wind speed or direction occurred at the top of this layer.

Spatial homogeneity in the thickness of the mixing layer was assumed to exist across the modeling region in the Las Vegas Valley. On occasion, particularly at certain times of the day, slight spatial differences in mixing depth were indicated from the helicopter temperature profiles. The indicated differences were generally close to the resolution limit of the helicopter data.

Two general modifications to each of the reported data sets were made in order to facilitate operation of the APSM. First, a minimum constant value of the mixing depth of 5 m was specified for the nocturnal hours. Actually, a surface-based radiation temperature inversion was present in the valley during this interval for each of the reported data sets. The minimum

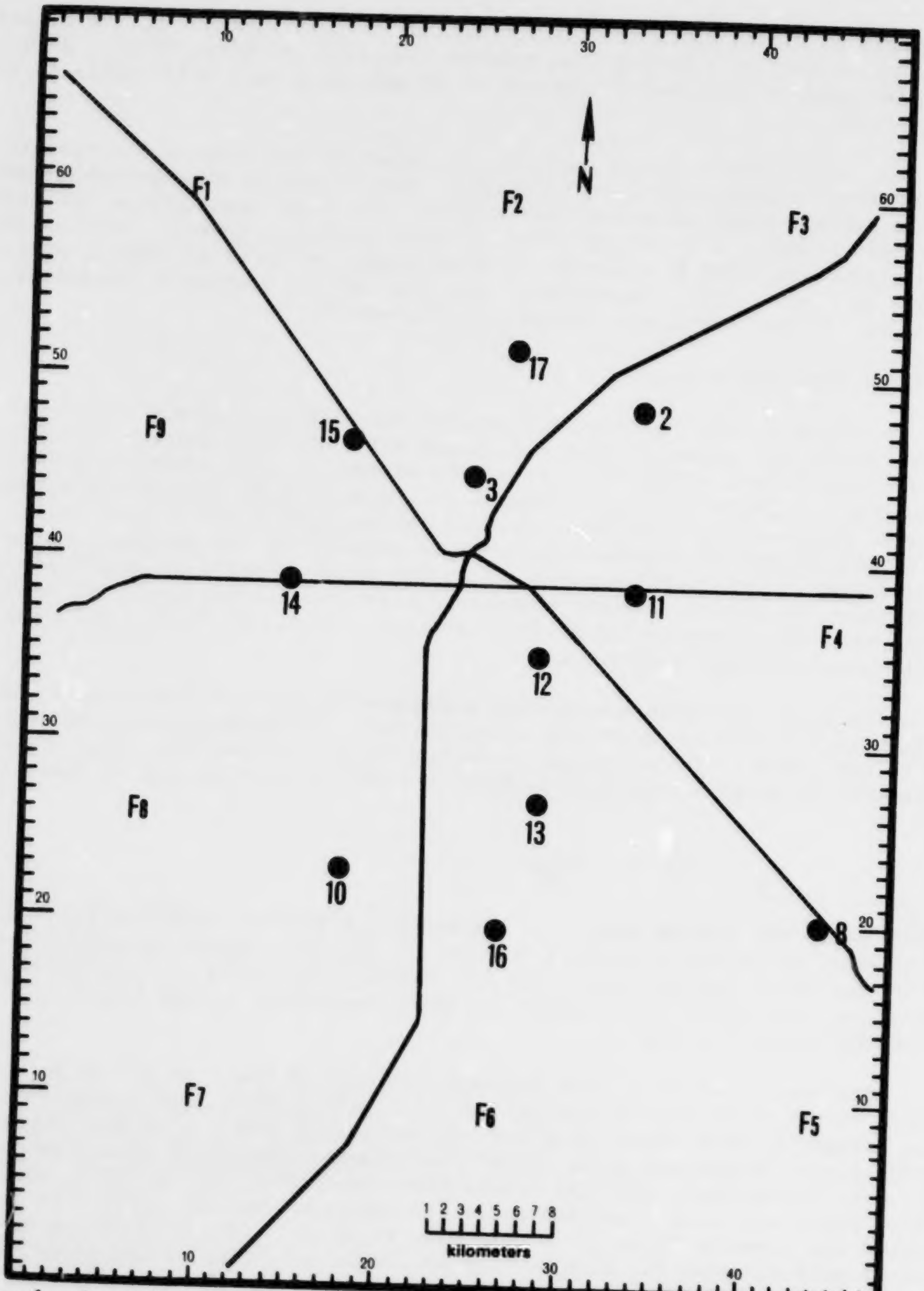

10
20
30
40
60
50
40
30
20
10
N
F1
F2
F3
F4
F5
F6
F7
F8
F9
17
2
15
3
14
11
12
13
10
16
8
1 2 3 4 5 6 7 8
kilometers

Figure 6. Location of virtual wind stations relative to the actual stations in the modeling grid. Station numbers preceded by the letter F are virtual stations.

reference or mixing depth roughly corresponds to the thickness of the mixing zone in the wake of a moving road vehicle (Ranzieri and Ward, 1975). Road vehicles produce more than 90 percent of CO emissions on a daily basis in the local area.

The second modification was concerned with the handling of the transition period from the occurrence of the maximum mixing depth to the reestablishment of the surface-based inversion near sunset. The field measurements indicated that this transition is accomplished in about an hour. However, each of the data sets was altered by allowing this transition to occur gradually, beginning 2 to 3 hours prior to sunrise. This was done to guarantee computational stability of the numerical formulation of the APSM.

Vertical Eddy Diffusivity

Profiles of vertical eddy diffusivity for each grid volume in the Las Vegas Valley are computed using a computer algorithm (see Chapter III, Liu et al., 1977) from values of near-surface horizontal wind speed, roughness parameter, height of reference level (i.e., mixing depth or elevated stable layer), exposure class and cloud cover. Information on cloud cover is obtained from hourly weather observations made at the NWS station located at McCarran International Airport. Exposure class at night is specified in terms of cloud cover. Daytime exposure classes require sun angle determinations which are computed using local latitude, longitude, time of day, and Julian date as input parameters.

Values of the surface roughness parameter (z_o) for inclusion into the diffusivity scheme are estimated using the bulk aerodynamic technique devised by Lettau (1969). The technique considers the height, surface area, and distribution of surface roughness elements exposed to the wind and is formulated as:

$$z_o = \left(\frac{h^*}{2}\right) \cdot \left(\frac{s^*}{S^*}\right) \qquad (6)$$

where h* is the average height of the roughness elements within a horizontal grid area, s* is the silhouette area of the average element exposed to the wind, and S* is the lot area. The lot area is the quotient of the total surface area over which the elements are being considered to the number of elements within the area.

Average values of z_o were computed for each of the 1-km x 1-km horizontal grids of the model area in the valley. For this purpose, representative land-use categories were established and percentages of them within each horizontal grid element determined using aerial photographs, results of visual ground surveys, street maps, and real estate maps and charts. Values of z_o calculated using the above formulation for the specific land-use categories established are shown in Table 2. A composite value of z_o for each of the horizontal grid elements was then derived by linear weighting of the percent coverage of each land-use category existing within the element.

TABLE 2. ROUGHNESS PARAMETER FOR LAND-USE CATEGORIES IN THE LAS VEGAS VALLEY

Land-Use Category	z_o (m)
1. Undisturbed desert: shrubs 2 m high and 1 m wide, spaced about 5 m apart	0.05
2. Disturbed desert: shrubs 1 m high and 0.5 m wide, spaced about 3 m apart	0.01
3. Residential: new subdivisions; one-story structures and few or small trees	0.40
4. Residential: older subdivisions; one-story structures and mature trees	0.50
5. Commercial: one to three-story structures with small to medium parking areas	0.30
6. Industrial: one-story structures with large parking and open areas	0.10
7. Downtown: high rise structures	1.00

Variations in silhouette area and hence of z_o as a function of both wind direction and season of the year were assumed to be negligible in the valley. These are not considered to be severe restrictions since tree cover, particularly deciduous species, is quite sparse, agricultural activity is minimal, and land-use tracts are relatively homogeneous.

COMPARISONS OF PREDICTIONS AND MEASUREMENTS

The APSM was exercised, utilizing the data base described above, for 6 days in the Las Vegas Valley. In this section, model predictions and measurements are compared.

The relative magnitudes of predictions and measurements can be compared by making plots of the two sets of data for each validation day independent of the location and the time. Ideally, the regression line calculated for such a plot would have a slope of one. When the measurements are plotted on the ordinate and the predictions on the abscissa, if the slope is less than one but greater than zero, then the predictions tend to be high relative to the measurements. If the slope is greater than one, the predictions tend to be low relative to the measurements.

Table 3 presents linear correlation coefficients and regression parameters for the 6 days of the validation study. Also listed are the number of data points used in the statistical analyses. It is apparent from the slopes of the regression lines that, in general, the model tends to underpredict.

TABLE 3. STATISTICAL COMPARISON OF PREDICTED AND MEASURED CO CONCENTRATIONS

Day	Number of Data Points	Correlation Coefficient	Slope	Intercept
Dec. 3, 1975	92	0.76	1.62	- 1.23
Dec. 4, 1975	91	0.73	0.91	0.26
Jan. 14, 1976	79	0.74	1.09	0.02
Jan. 16, 1976	67	0.42	0.48	0.78
Jan. 21, 1976	83	0.91	1.22	- 0.87
Jan. 22, 1976	92	0.77	0.99	- 0.41

Figures 7 and 8 are diagrams of predictions and measurements for January 21, 1976, and December 3, 1975, respectively. As shown in Table 3, January 21, 1976, yields the best correlation between predictions and measurements. The correlation for December 3, 1975, is reasonably high, but the measurements tend to be much higher than the predictions. One interesting feature of Figures 7 and 8 is the large number of points below the unit slope and zero intercept line for measured concentrations below 5 parts per million (ppm). In fact, the portion of the plot for January 21, 1976, below measured concentrations of 10-ppm is fitted quite closely by the line of unit slope and zero intercept.

For most of the validation days, and at most of the measurement sites, the trends of the predicted concentrations follow closely the trends of the measurements. As expected from the results in Table 3, the magnitudes of the predicted minima are close to the minima of the measurements, and the predicted and measured maxima do not compare well. The temporal variations of the predicted and measured CO concentrations are compared in Figures 9 through 14 for four of the measurement sites. The Arden and Nellis sites were chosen to represent model predictions at the remote monitoring locations and the remaining sites reflect predictions and measurements at the sites under the influence of the urban CO emissions.

The late afternoon peak in the measured CO concentration that occurred on January 16, 1976 (see Figure 12), seems to reflect microscale effects on measured concentrations which cannot be reproduced by the mesoscale model. The Shadow Lane, Casino Center, and East Charleston monitoring sites are separated by a maximum of 5 km yet on that day East Charleston had virtually no afternoon concentration peak while concentrations at Shadow Lane and

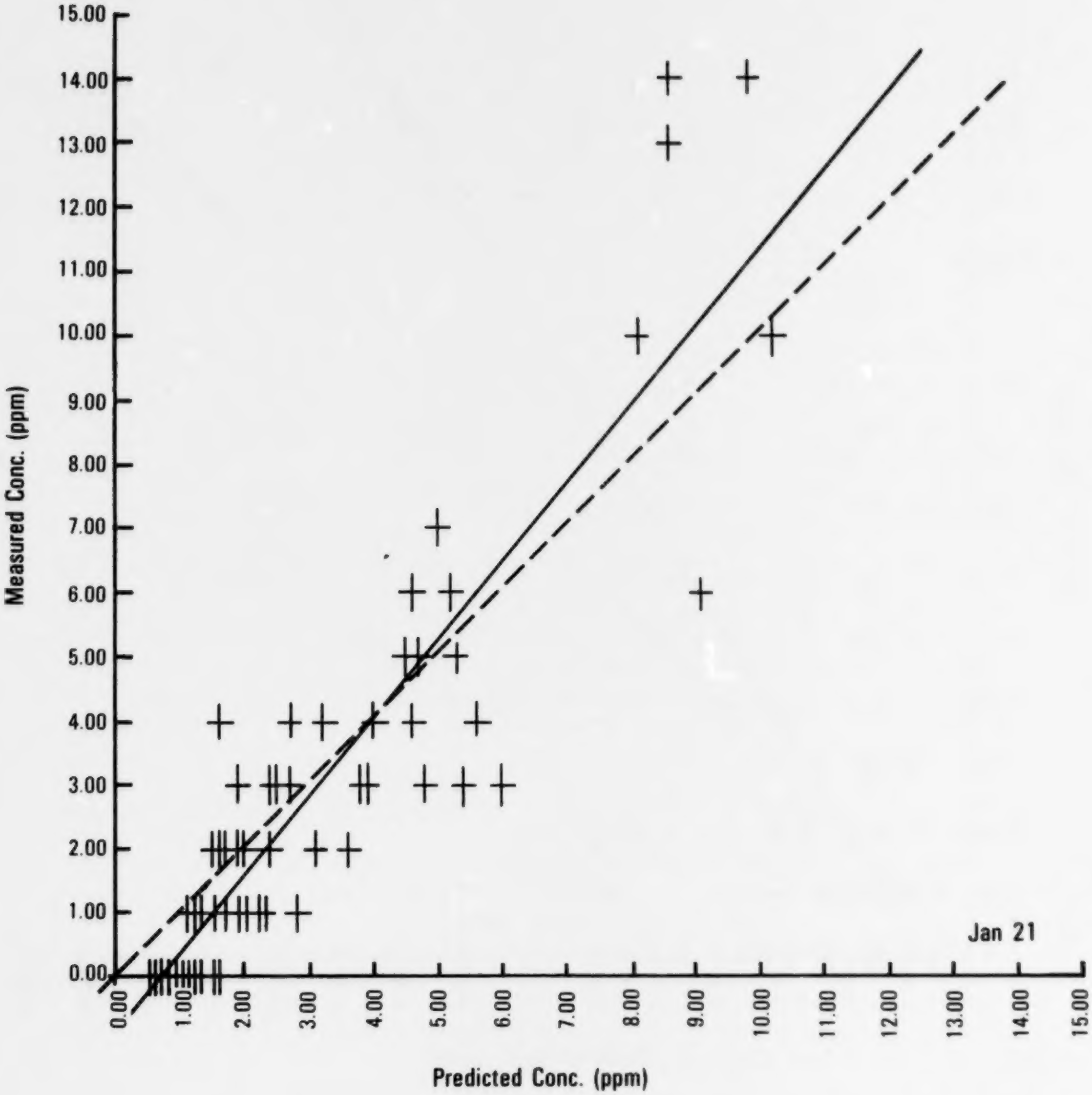


Figure 7. Diagram of predicted vs. measured CO concentration in the Las Vegas Valley on January 21, 1976. The solid line is the regression line. The dashed line is of unit slope, zero intercept.

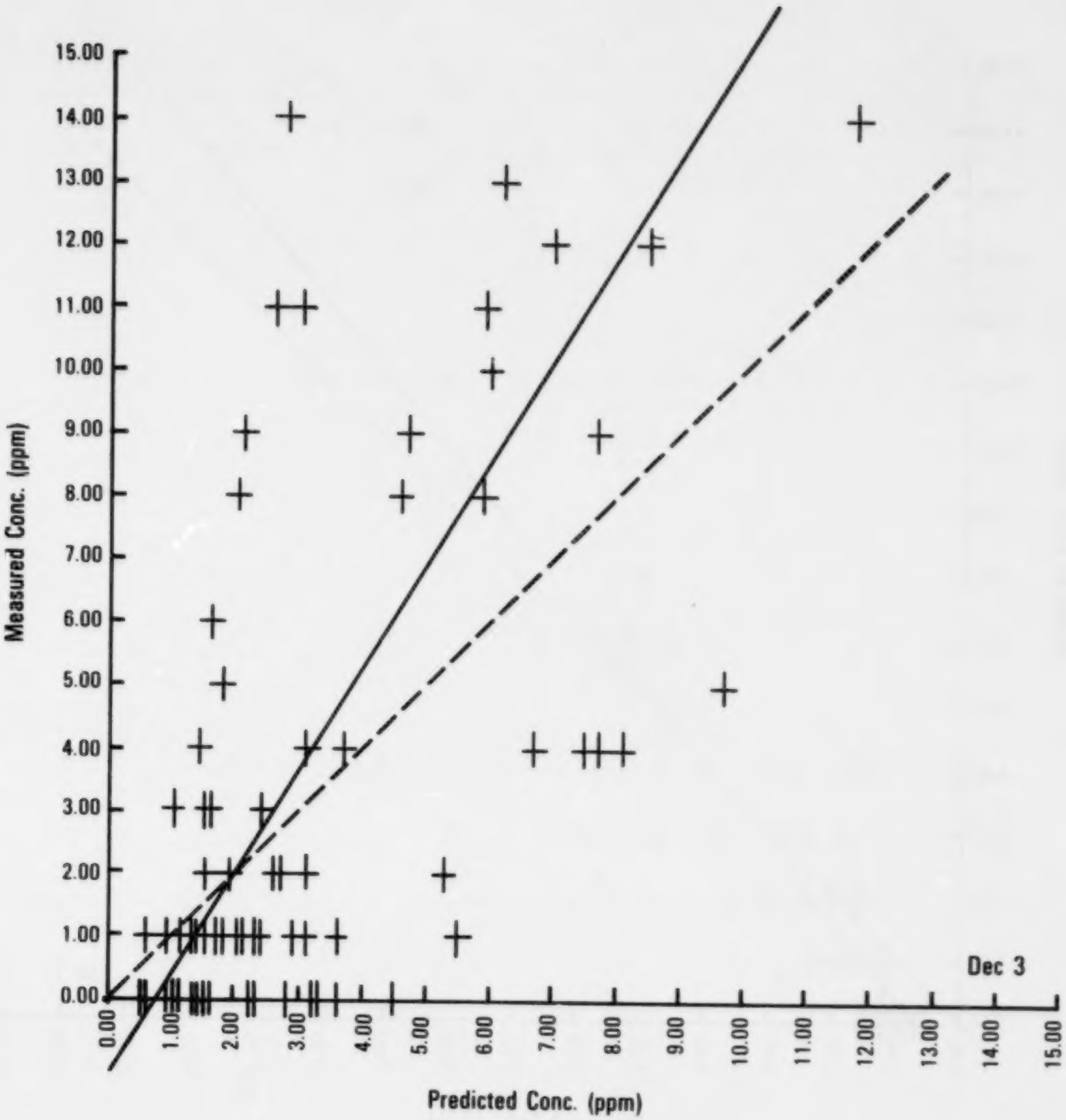


Figure 8. Diagram of predicted vs. measured CO concentration in the Las Vegas Valley on December 3, 1975. The solid line is the regression line. The dashed line is of unit slope and zero intercept.

Casino Center reached approximately 8 ppm and 14 ppm, respectively. The model predicts an afternoon peak at all three stations. The reason for the discrepancy between the measurements and predictions cannot be specified with certainty. However, an explanation based on the wind direction and the locations of the monitoring stations relative to sources appears to be reasonable. The stations at Shadow Lane and at Casino Center are both surrounded by areas of heavy traffic. The region to the east of the East Charleston site has a lower source density, and the region to the west has a source density similar to the areas surrounding the other two sites. During the afternoon of January 16, 1976, the wind at the two meteorological stations nearest to the East Charleston site was out of the northeast. On the other 5 days studied, the wind was blowing from the west at this time of day. Hence, it would appear that the change of the wind direction may have had a more pronounced effect on the CO concentration at East Charleston than at the other two sites.

Changing the mixing depth or the atmospheric stability inputs to the model can change the magnitude of the concentrations as well as the temporal dependence of the pollutant concentrations. However, because we assume that the stability and the mixing depth are spatially uniform, any change in these parameters will lead to a change in concentration of the same size at all locations. It is clear in Figures 10 and 11 that the low concentrations predicted at the Shadow Lane station could not be improved by lowering the inversion heights or increasing the stability without making the correspondence between measured and predicted concentrations worse at the other stations. This fact suggests that either the winds have not been adequately estimated or there is some microscale phenomenon affecting the Shadow Lane CO concentrations in these two instances. The initial conditions are unlikely to be the cause of the low prediction because the poor correspondence between measurements and predictions also occurs in the afternoon. It should be noted that a high pollution concentration gradient frequently occurs in the vicinity of the Shadow Lane station. This situation could magnify the discrepancies between prediction and measurements with small changes (or errors) in wind direction.

Failure of a model like the APSM to simulate correctly very high measured values of CO often reflects either a microscale phenomenon not resolved by the model or uncertainties in the emissions inventory or in the interpolated wind field. An explicit example of uncertainties in the interpolated wind field significantly affecting the location and magnitude of high CO values is discussed below. No attempt in the current study was made to adjust the emissions inventory or to treat microscale effects although such adjustments would be expected to improve the validation results.

At 1600 LST on January 16, 1976, a large horizontal shear existed in the surface wind field between sites L and Z and sites H and K as shown in Figure 15. As expected, this resulted in large spatial variations in the automated, interpolated wind field in the vicinity of CO monitoring sites D, S, C, and E and generally poor agreement between predicted and measured CO values at these sites. The agreement was improved substantially when virtual stations in the manner previously discussed were added between the affected wind measurement sites prior to running the automated interpolation scheme.

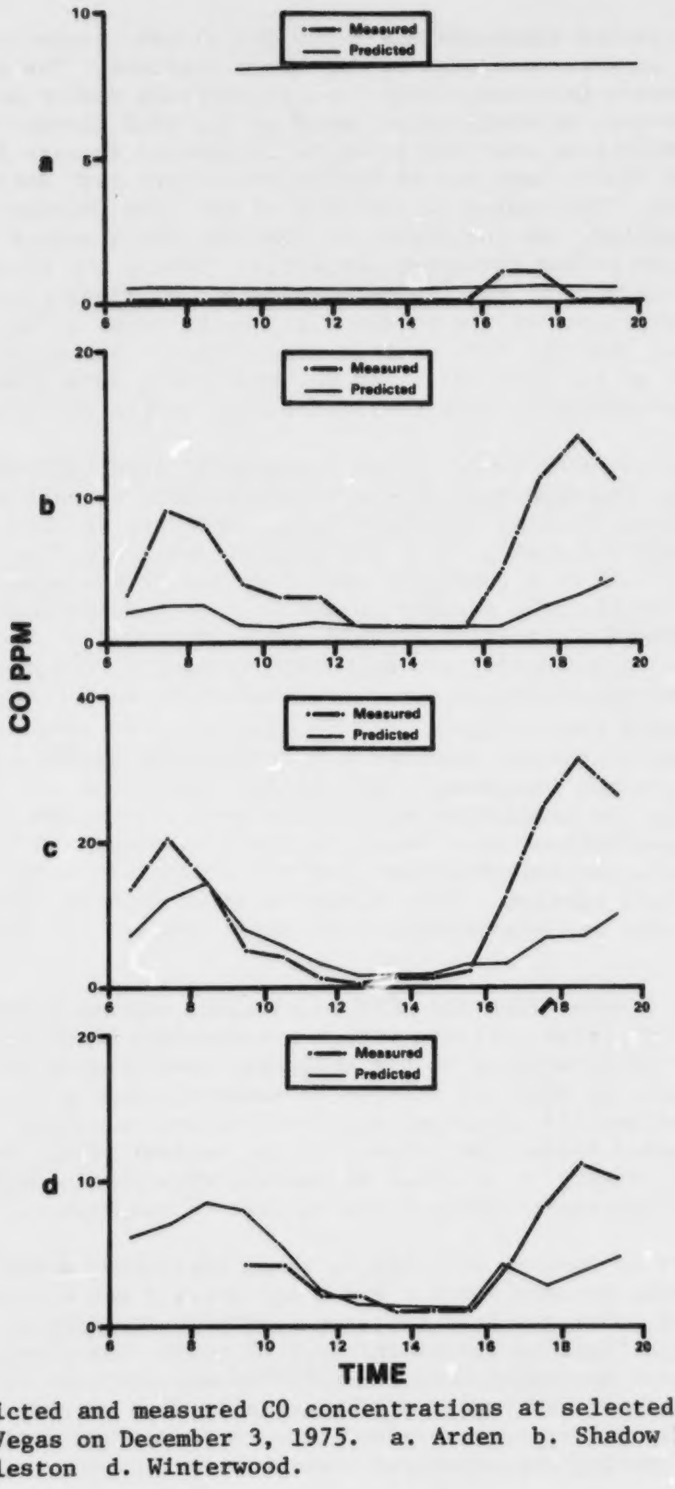


Figure 9. Predicted and measured CO concentrations at selected sites near Las Vegas on December 3, 1975. a. Arden b. Shadow Lane c. East Charleston d. Winterwood.

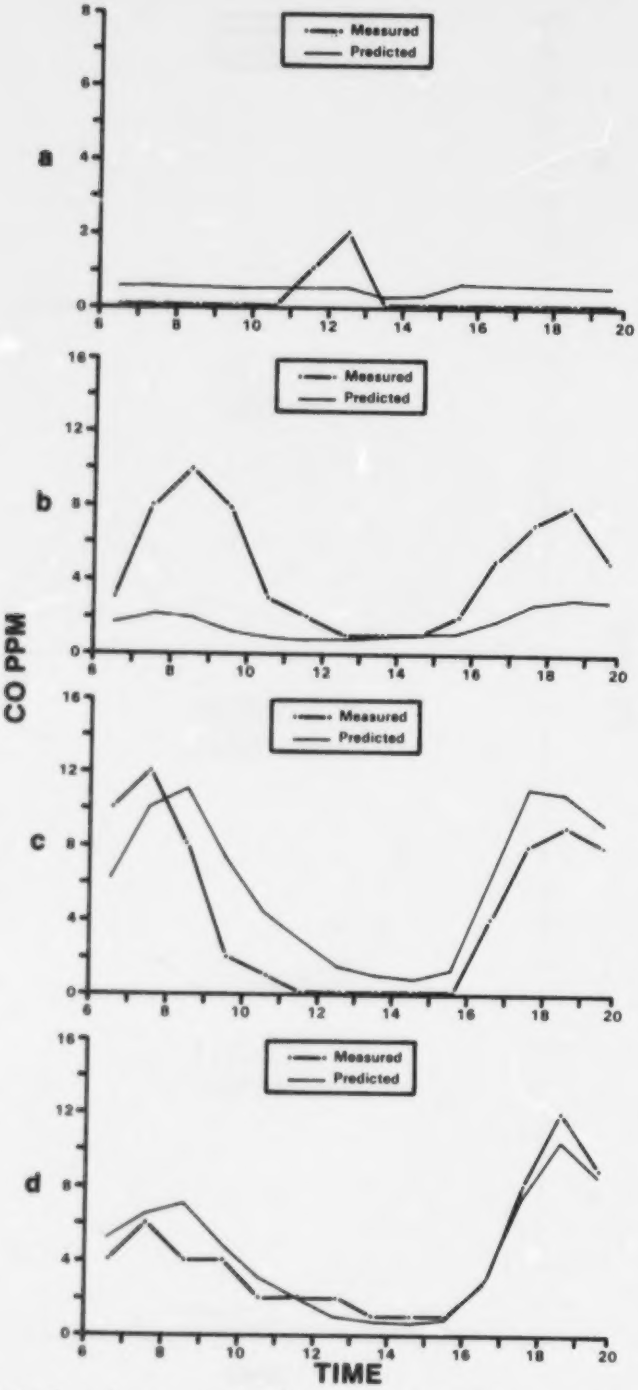


Figure 10. Predicted and measured CO concentrations at selected sites near Las Vegas on December 4, 1975. a. Arden b. Shadow Lane c. East Charleston d. Winterwood.

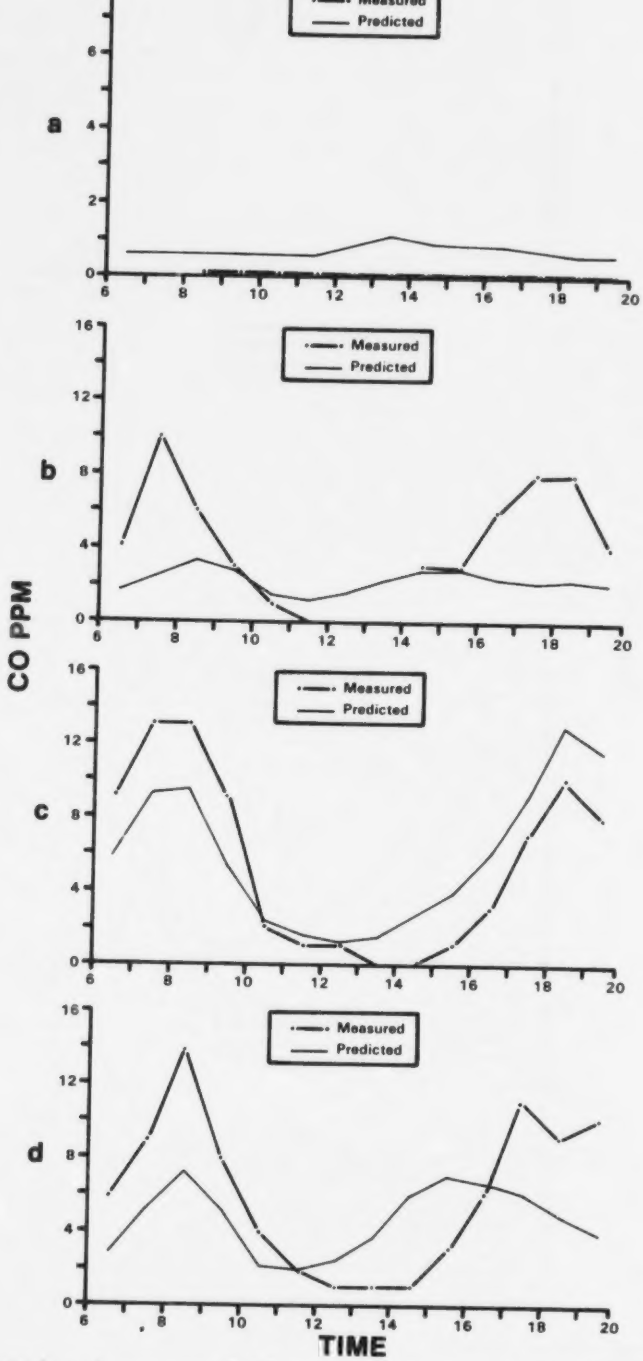


Figure 11. Predicted and measured CO concentrations at selected sites near Las Vegas on January 14, 1976. a. Arden b. Shadow Lane c. East Charleston d. Casino Center.

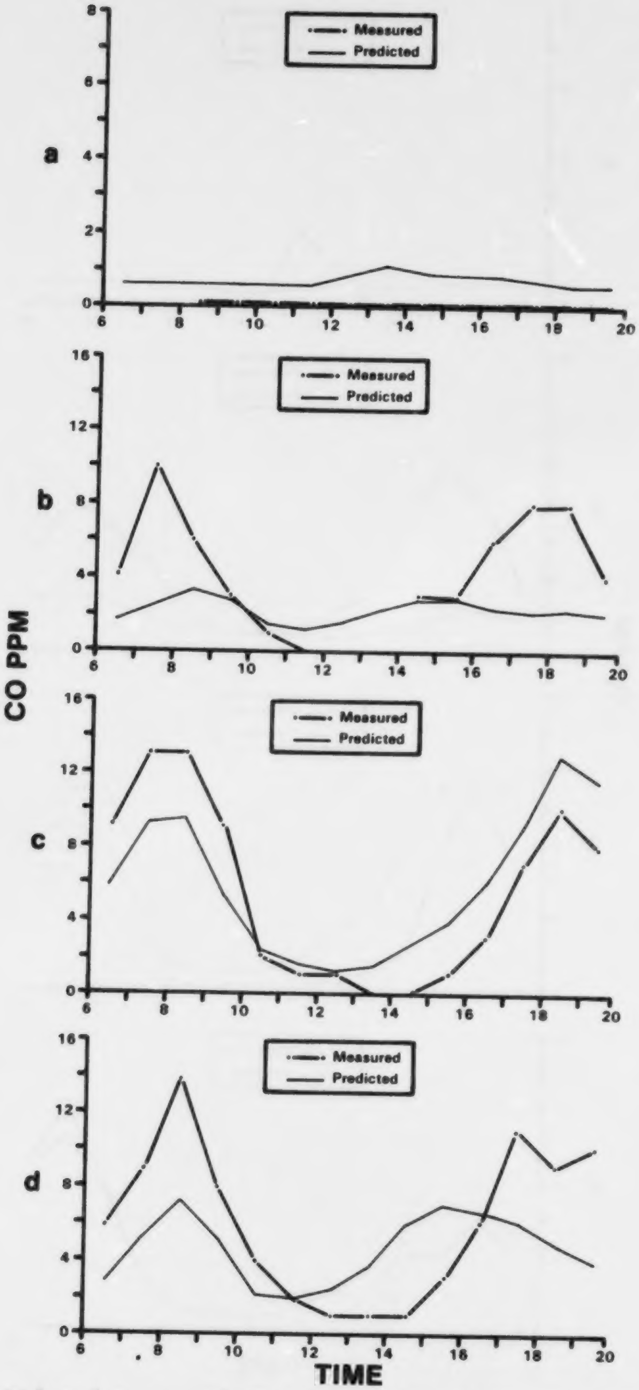


Figure 11. Predicted and measured CO concentrations at selected sites near Las Vegas on January 14, 1976. a. Arden b. Shadow Lane c. East Charleston d. Casino Center.

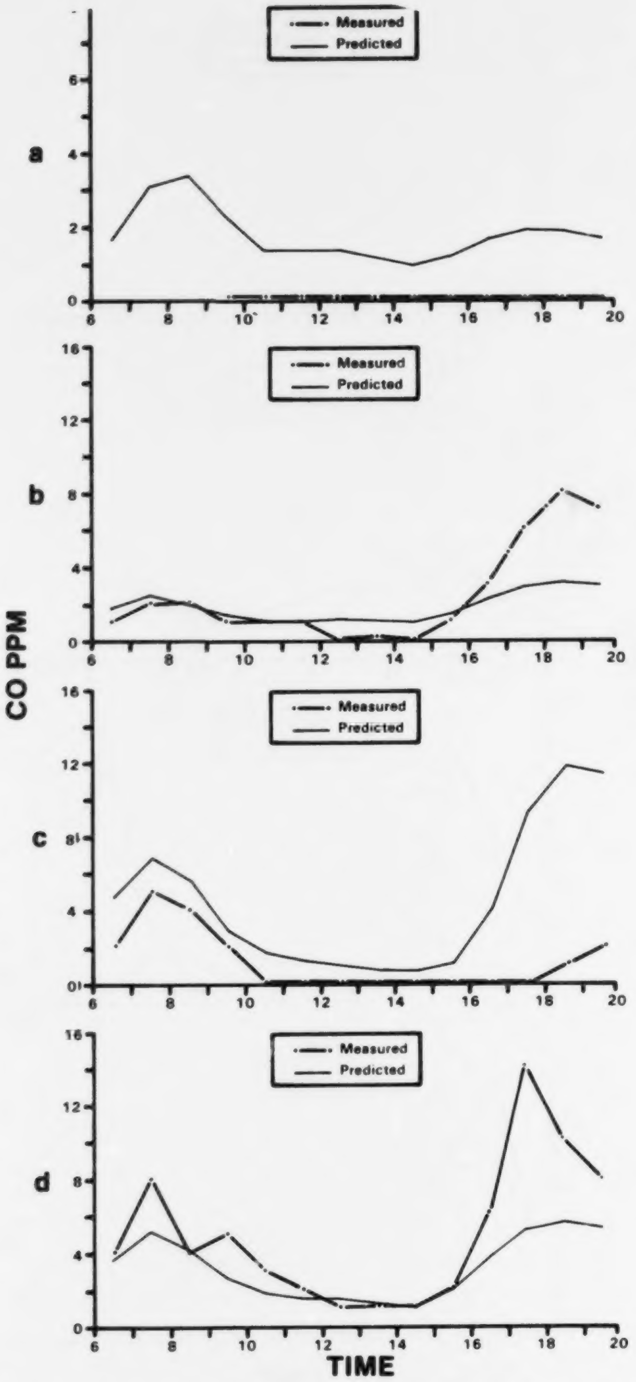


Figure 12. Predicted and measured CO concentrations at selected sites near Las Vegas on January 16, 1976. a. Nellis b. Shadow Lane c. East Charleston d. Casino Center.

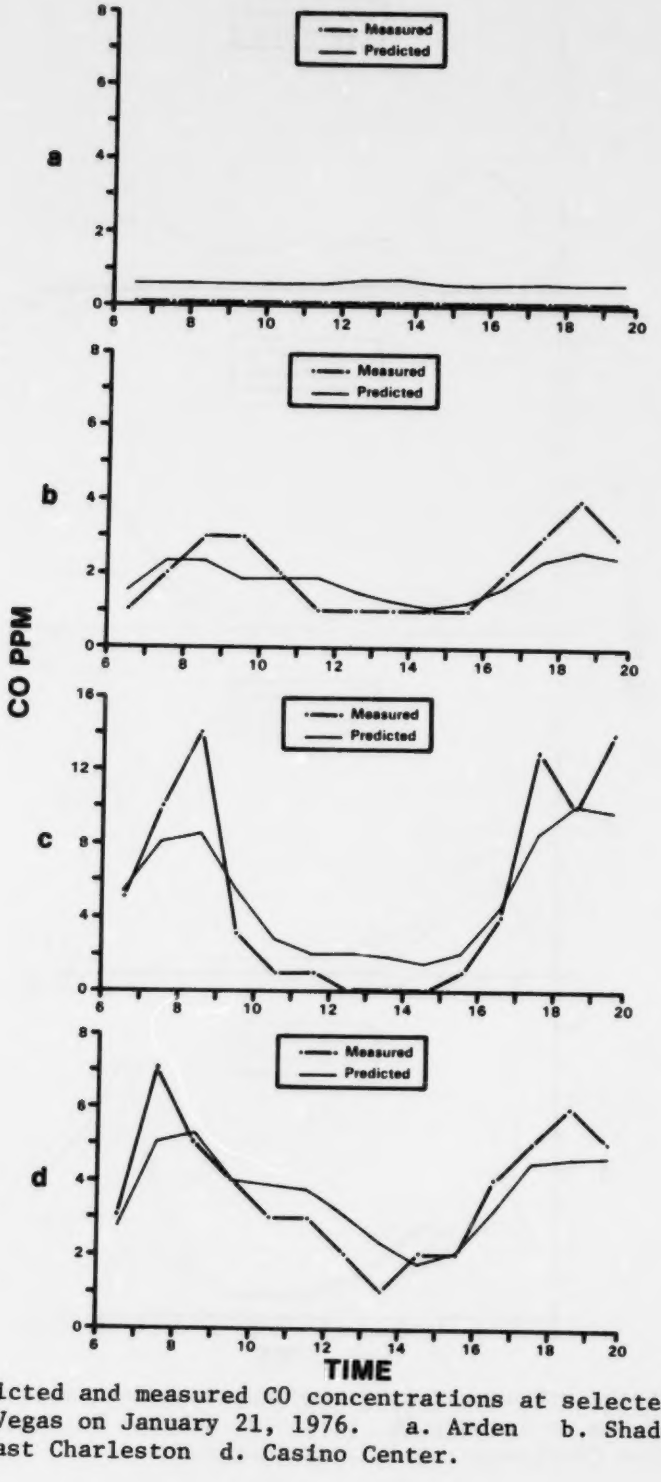


Figure 13. Predicted and measured CO concentrations at selected sites near Las Vegas on January 21, 1976. a. Arden b. Shadow Lane c. East Charleston d. Casino Center.

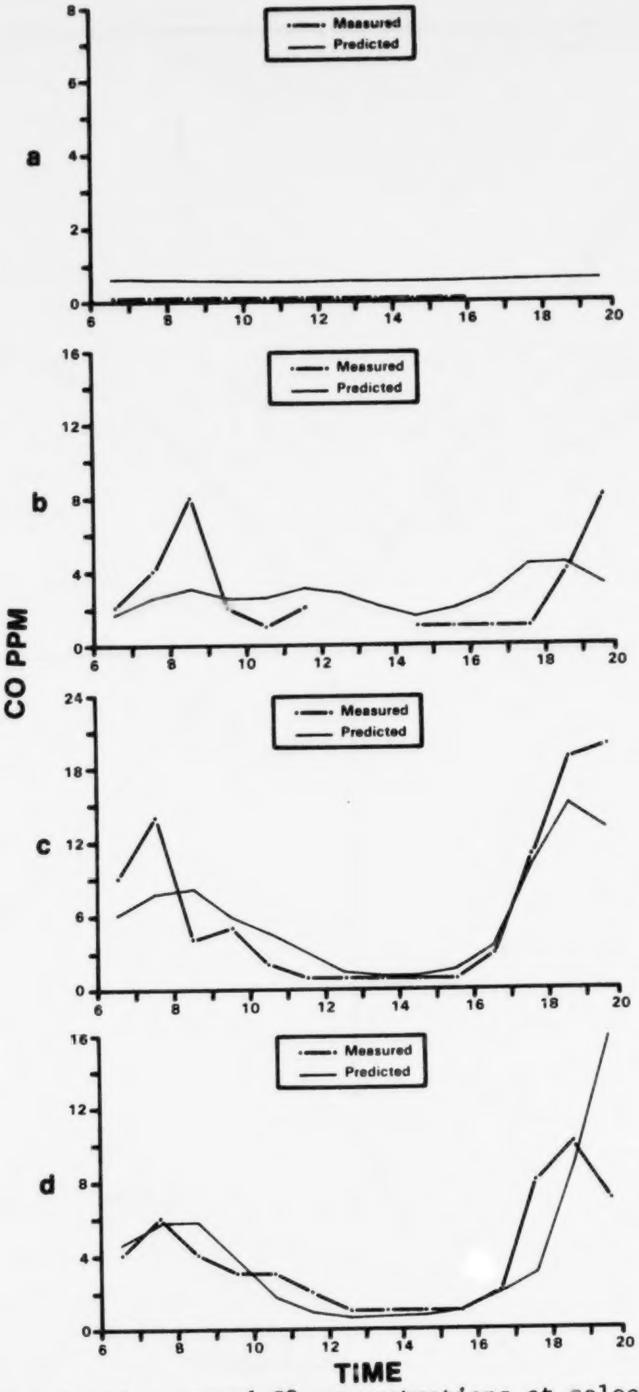


Figure 14. Predicted and measured CO concentrations at selected sites near Las Vegas on January 22, 1976. a. Arden b. Shadow Lane c. East Charleston d. Winterwood.

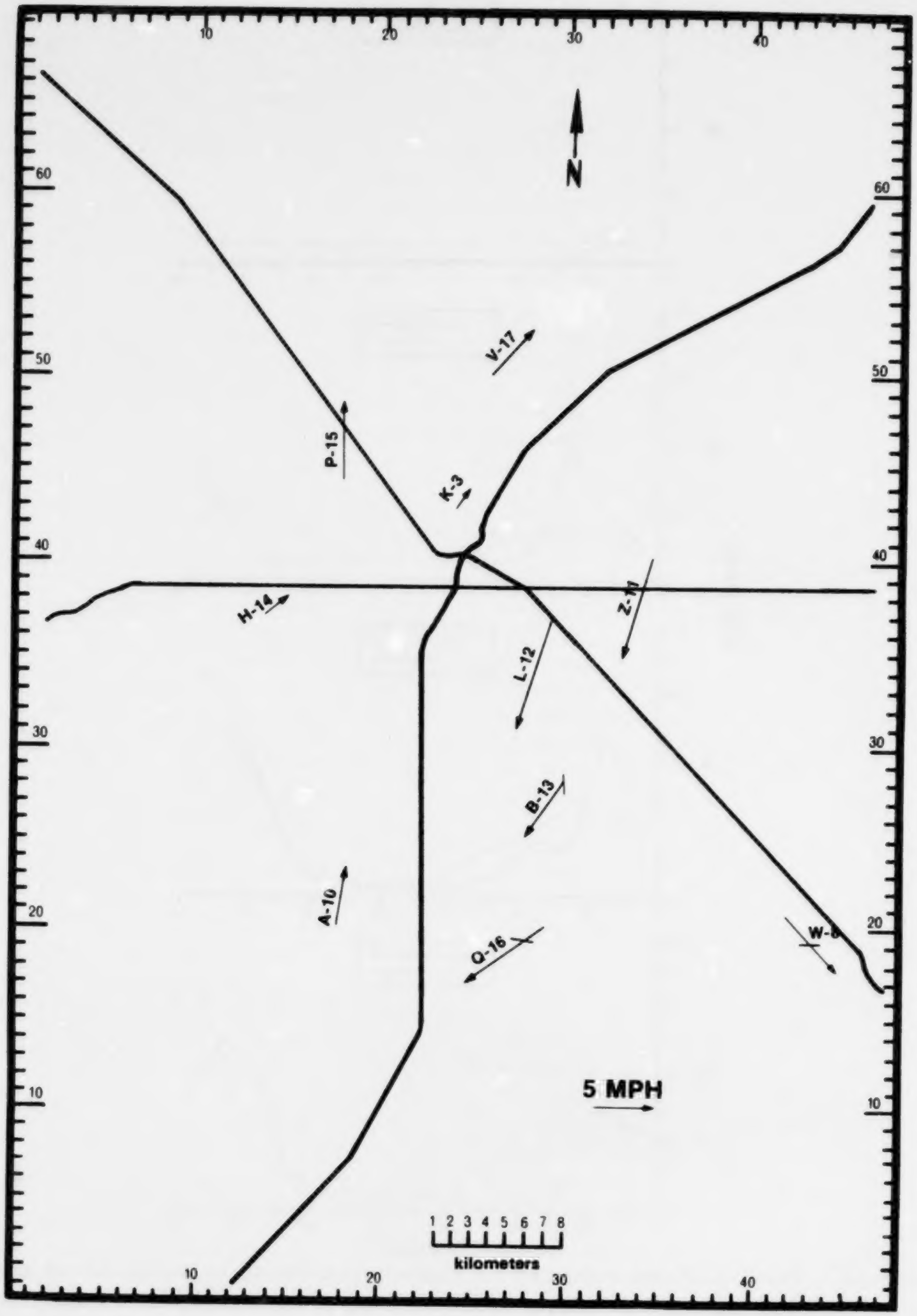

10
20
30
40
N
60
50
40
30
20
10
60
50
40
30
20
10
V-17
P-15
K-3
H-14
Z-11
L-12
B-13
A-10
Q-16
W-8
5 MPH
1 2 3 4 5 6 7 8
kilometers
10
20
30
40

Figure 15. Wind data for 1600 PST, January 16, 1976.

A detailed study of the APSM to determine the effect of uncertainties in input parameters was not conducted as part of the present model validation effort. Such uncertainties may be in the data themselves or in the interpolation routines utilized to prepare the data for use with the model. However, a study on this subject was conducted by Liu et al. (1976a), using an earlier version of the APSM with data appropriate for the Los Angeles metropolitan area. In the study, wind speed, vertical eddy diffusivity, mixing depth, or pollutant emission rate was varied within its expected range of uncertainty with the other parameters kept at specified base values. The relative change in CO concentrations associated with these variations were than determined through model simulations for a specific data base in the area. The results were evaluated in terms of deviations from areawide averages of CO concentrations. Qualitatively and in a relative sense, the simulated CO values were most sensitive to changes in wind speed, less sensitive to changes in mixing depth and pollutant emission rates, and least sensitive to changes in the vertical eddy diffusivity. For further details on the study, the paper by Liu et al. (1976a) should be consulted.

The temporal variations of the CO concentrations shown in Figures 9 through 14, the diagrams in Figures 7 and 8, and the results of the statistical analysis shown in Table 3 illustrate how well the predictions compare with the measurements at the monitoring sites. However, to expect a highly favorable comparison of the predictions with the measurements by these criteria alone is overly optimistic, considering the uncertainties in the input data for the model. The criteria presented thus far for comparing predictions with measurements do not take into consideration the possibility of slight shifts in the spatial distribution of the predictions relative to the measurements. Shifts might arise from errors in the input data (e.g., the emissions distributions or the windfield). Hence, if an error of 0.5 km/h in a wind vector (or perhaps an error in the direction) arose from the interpolation procedure, it would not be unreasonable to expect that after several hours of simulation a measurement might be in better agreement with the prediction at a location one or more grids from the monitoring site than at the site itself. Such shifts of the predictions can be detected only by inspection of the predicted ground-level concentrations on the entire grid system.

This inspection would be a formidable task because of the quantity of output from the model, but a simplification of the format of the model output made it less difficult. The predictions were converted into isopleth diagrams, with lines of constant CO concentration printed out on the grid at intervals of 2 ppm. Isopleths for predictions and the measurements at each of the monitoring sites for each hour of each validation day are presented in Appendix C.

A fair appraisal of model performance can be obtained by comparing the temporal distributions of the predictions and the measurements (in Figures 9 to 14) with the corresponding spatial distributions for the hours of interest (in Appendix C). From Figure 10, it appears that the model does poorly at reproducing the magnitudes of the peaks in CO concentrations in the morning and afternoon at Shadow Lane. The isopleth diagrams for December 4, 1975, show that the predicted concentration gradients in the vicinity of Shadow Lane at the times of these two peaks are very sharp. At any hour, a slight shift of the predicted concentration distribution to the west would result in a very close match between predictions and measurements. The isopleth diagrams support similar observations in many other cases of substantial deviations between predictions and measurements but generally show that the model does well in predicting the general location of hot spots or local maxima.

The highest values for CO occur in the vicinity of the Las Vegas Wash area. Since this is an area of convergence for nighttime drainage flow, pollutants are expected to collect here, resulting in high values following the evening traffic peak.

The measured CO concentrations on all days for the hours from 1700 to 2000 indicate very sharp concentration gradients between East Charleston and Casino Center. These features of the concentration distributions cannot be predicted by the model without more highly resolved meteorological data or some knowledge of the subgrid-scale processes important in the vicinity of East Charleston.

In general, when the predicted concentrations exceed 10 ppm there are very sharp concentration gradients in the central city area around the Shadow Lane, Casino Center, and East Charleston measurement stations. The spatial scale over which concentrations change is much less than the distance between the wind measurement stations. Hence, we expect the uncertainty in interpolated wind fields to have a significant effect on the comparison between measured and predicted concentrations at these central city measurement stations.

Finally, the validation results can be assessed in terms of the individual monitoring stations with emphasis on the specific locations regarding land use and emission sources. For example, the Winterwood and Henderson stations lie in the Wash area where the model appears to perform well in predicting both diurnal trends and peaks (except for microscale influences).

The same is true for the East Charleston station which also lies in the Wash but is near the downtown area. The model does well in predicting diurnal trends but misses the magnitude of the peaks more so than in the Wash area. Many of these peaks are definitely associated with microscale effects due to location of station (as evidenced by observed wind directions).

Arden and Nellis are background stations where little diurnal variability is observed in the measurements. The model depicts this well at Arden. At Nellis it indicates some diurnal variability associated with apparent emissions. It is likely that these are the result of the assumption of apportionment of Nellis emissions from aircraft to several squares. These emissions are probably not reflected in surface concentrations at outlying squares as aircraft operations here are aloft. Also, emissions in the square for the Nellis site are probably downwind of it but this model cannot account for such microscale emissions effects.

The Shadow Lane and northwest residential stations are represented by residential/commercial or residental land use. At these sites the model simulates the diurnal trends but not the magnitude of the peaks. Both sites are in an area of some heterogeneity in emissions which cannot be resolved well by the model on the mesoscale.

MODEL VALIDATION SUMMARY AND CONCLUSIONS

The APSM was evaluated for CO for the Las Vegas Valley using data for six dates which were basically chosen for their meteorological potential for high pollutant concentrations. The results show that the model generally predicted trends at stations and distributions, including the relative location of mesoscale (1-km by 1-km resolution) of hot spots or local maxima well. It did not perform as well in predicting the absolute values of these peaks, especially in the downtown area. These discrepancies, though, can usually be accounted for based on either uncertainties in input data or on microscale phenomena. The hourly averaged point-by-point comparison between predictions and measurements of the stations taken collectively yielded linear correlations between 0.7 and 0.9 for five of the six validation dates.

Results of past model validation studies indicate that point-by-point comparisons between pollutant predictions and measurements on an annual or seasonal basis generally result in linear correlation coefficients between about 0.6 and 0.9 (e.g., Koch and Thayer, 1972; Slater and Tikvart, 1974). Limited results are available on hourly comparisons. Those for sulfur dioxide have reported as yield coefficients between 0.2 and 0.6 (e.g., Koch and Thayer, 1972; Shirr and Shieh, 1974). Johnson et al. (1973) reported coefficients for CO between 0.4 and 0.7 but utilized monitoring sites in the immediate vicinity of roadways and included a microscale submodule for specific microscale effects. Liu et al. (1976b) reported coefficients for CO in the range 0.6 and 0.8 for models finely tuned to a specific metropolitan area.

Thus, the comparisons between predictions and measurements on a point-by-point basis for the present study are at least as good as those presented in the literature. In addition, as required by the project objective, it generally predicted distributions well,including relative locations of peaks. As a result, the APSM is considered at least adequate for its proposed task in this project--that of providing a data base for exercising the network siting procedure in the Las Vegas Valley as a demonstration case.

V APPLICATION OF SITING METHODOLOGY TO THE LAS VEGAS VALLEY

As illustrated in Figure 1, the demonstration of the siting methodology consists of two parts. The first part, the model validity study, was discussed in Chapter IV. This chapter addresses the second part--the application of the methodology for the selection of CO monitoring sites in the Las Vegas Valley.

OVERVIEW

A review of various considerations pertaining to the selection of air quality monitoring sites was presented earlier (Liu et al., 1977). It was emphasized that the formulation of an objective scheme for selecting monitoring sites requires a clear statement of the goals or objectives of monitoring. For the sampling of air contaminants, several possible objectives were listed:

- Compliance with air quality standards.
- Determination of long-term air pollution trends.
- Enforcement of regulations on pollutant emissions.
- Estimation of regional air pollutant fluxes.
- Procurement of data for air quality model development or validation.

For Federal or regional air pollution control agencies, compliance with regulations and standards is probably the most important objective for air quality monitoring, and it is the principal objective in the design of the siting methodology.

In the methodology, the desirability of placing an air quality monitor at a given location is measured by a Figure of Merit. Quantitatively, the Figure of Merit for a particular location is defined as the product of an air quality index (either observed or expected) and the associated frequency or probability of occurrence:

$$F = \sum \text{(Air Quality Index)} \cdot \text{(Probability of Occurrence)}. \qquad (7)$$

The summation is to be performed over all meteorological scenarios that lead to high air pollution concentrations. The Figure of Merit is weighted by the frequencies of occurrence of scenarios because the pollutant concentration at any location is a function of the prevailing meteorological conditions. Thus, it varies significantly with time. Consequently, air quality information related to a single event or period would not necessarily be the best index for the determination of a permanent or semipermanent site for a monitoring station. By careful selection and characterization of the meteorological scenarios, it may be possible to include the effects of variable meteorological conditions in the selection of the optimum site by means of equation (7).

The air quality index in equation (7) may be chosen either as the concentration of a specific pollutant for general air quality monitoring or, for the case of detecting measurements which exceed an ambient air quality standard (AAQS), as a delta function defined by

$$\delta = \begin{cases} 1 & \text{if the observed or expected concentration exceeds the AAQS,} \\ 0 & \text{if not.} \end{cases} \tag{8}$$

It is possible that in the first case, high values of the Figure of Merit may be calculated for locations which never exceed the AAQS or some large fraction of it. Such locations may be excluded from consideration as potential monitoring sites by truncation of the calculation for them. In the case of locating a site for the measurement of many pollutants, the air quality index can apparently be generalized using a composite index $\bar{c}^*$,

$$\bar{c}^* = \sum_{i=1}^{N} w_i^* c_i \quad , \tag{9}$$

where c_i is the observed or expected concentration of species i, and w_i^* is the weighting factor reflecting the importance of pollutant species i.

METEOROLOGICAL SCENARIOS PERTAINING TO HIGH CO CONCENTRATIONS

Selection of optimal locations for CO monitoring stations by the Figure of Merit technique was accomplished using the results of simulations with the APSM as a data base. The simulations were run on meteorological scenarios developed from historical weather data supplemented by current aerometric information collected during the intensive and routine field sampling programs. Analysis of historical CO data, especially that with concentrations from slightly less than to greater than the NAAQS, in relation to the prevailing meteorological situation or pattern, should provide definitive information useful for scenario selection. Unfortunately, the historical aerometric data base in the Las Vegas Valley is insufficient for this purpose. Consequently, the meteorological pollution potential expressed as the ventilation rate discussed previously was substituted for the air quality data in the scenario selection process. This was not considered to be a severe restriction since the concentration of a relatively inert pollutant such as CO released primarily at near ground-level should be proportional to the ventilation rate (McCormick, 1968).

Ventilation rates were calculated using upper air data collected at McCarran International Airport. Specifically, 5 years of mixing depth and wind speed data were used for the period between 1959 and 1964. These data were available on magnetic tape from NOAA's National Climatic Center. Ventilation rates were only determined for 1600 LST data since a nocturnal surface-based temperature inversion usually existed locally at the time of the 0400 LST upper air sounding.

Initially, classification of meteorological situations into categories was accomplished through statistical analysis of data available on 850-millibar (mb) constant pressure charts. For this analysis, heights on the charts were available at intervals of 1 degree latitude and longitude for the contiguous United States and large portions of adjacent bodies of water. Six years of the data encompassing the Western United States and portions of the Eastern Pacific Ocean were utilized from a magnetic tape furnished by the NWS's NSO in Las Vegas. Objective classification was accomplished in the manner outlined by Lund (1963) and Roach and McDonald (1975). Basically, this involves establishing the linear correlation of heights on the constant pressure surface for all pairs of grid points. The charts or maps correlating highest with each other are grouped together to form classes. The percentage frequency of each class determines its probability of occurrence.

The results of the study for the period of the local CO season were not satisfactory. The classes chosen for the 850-mb constant pressure surface charts were not usually relatable to distinct features present on ground-level charts. In addition, a large percentage of charts from the data set could not be placed into discernible classes. It is likely that better results might be attained if ground-level data were utilized in the analysis. This expectation is supported by the fact that the transport and diffusion of ground-based emissions such as CO on a scale of the Las Vegas Valley will be largely determined by processes in the planetary boundary layer; the layer rarely extends to the 850-mb level except in mid-to-late afternoon. However, such ground-level data were not readily available.

Consequently, meteorological situations were grouped into classes through visual examination of historical ground-level weather charts. This was accomplished using data from 1959-1964 available on microfilm from the NSO. The classification was done using the entire data set and a selected portion of the data set for the local CO season. The selected data set consisted of the dates experiencing the lowest 20 percent of the ventilation rates. This subset of the data was assumed to encompass most of the situations for which the NAAQS would actually, or nearly, be exceeded. In each case, the frequency of occurrence of the chosen classes established the requisite probability of occurrence.

Comparisons between the resulting synoptic meteorological patterns or classes and the ventilation rates were subsequently made using discriminant analysis. A computer algorithm of the discriminant analysis procedure applicable to this problem has been devised by Meyers (1971). A detailed discussion of discriminant analysis is found in Hoel (1962). As in the previous case, the results of the comparisons were poor. That is, very few of them were statistically significant at the standard 5 percent level. The results are likely colored by the fact that the synoptic classes that evolved spanned a very narrow range of conditions, i.e., largely consisting of high pressure areas in various locations in relation to the Las Vegas Valley. In addition, pollutant transport and diffusion are determined by the details of atmospheric circulations which may not be readily divisible by a classification scheme based fundamentally upon synoptic scale weather features.

Because the above techniques yielded limited results, the scenarios were developed directly from the mixing depth and wind speed data for the dates experiencing the lowest 20 percent of the ventilation rates. For this purpose, a two-way contingency table involving *mixing depth and wind speed was devised* using this subset of the 5-year data set for the local CO season. The resulting table, also known as a test block, is presented as Table 4. Maximum mixing depth (1600 LST value generally corresponds to the daily maximum value) and average wind speed through this depth are, respectively, the ordinate and abscissa in the Table. Statistics on the mean and standard deviation of data values are provided in each block. The number of data sets (n) in each class is also shown.

TABLE 4. CLASSIFICATION OF METEOROLOGICAL SCENARIOS

Wind Speed (u = m/s)	Mixing Depth (H = m)					
	<200	200 - 400	400 - 600	600 - 800	800 - 1000	>1000
calm	*	u ∿ 0 H = 394 n = 1	u ∿ 0 H = 590 n = 1	*	*	*
0.3-1	*	u = 0.84 ± 0.23 H = 288 ± 44 n = 8	u = 0.82 ± 0.21 H = 507 ± 61 n = 26	u = 0.82 ± 0.21 H = 702 ± 53 n = 25	u = 0.88 ± 0.25 H = 848 ± 55 n = 8	u = 0.87 ± 0.19 H = 1237 ± 182 n = 7
1-2	u = 2 H = 185 n = 1	u = 1.60 ± 0.31 H = 342 ± 55 n = 11	u = 1.68 ± 0.52 H = 518 ± 54 n = 27	*	*	*
2-3	u = 2.1 H = 56 n = 1	u = 2.7 H = 320 n = 1	*	*	*	*
3-4	u = 3.5 H = 163 n = 1	u = 3.5 H = 266 n = 1	*	*	*	*
4-5	*	u = 4.7 H = 355 n = 1	*	*	*	*
5-6	*	u = 5.4 ± 0.1 H = 309 ± 31 n = 2	*	*	*	*
6-7	u = 6.4 H = 107 n = 1	*	*	*	*	*
7-8	*	*	*	*	*	*
8-9	*	u = 9 H = 220 n = 1	*	*	*	*
>9	*	*	*	*	*	*

*indicates n = 0

The data in the test block were further grouped according to wind speed alone: calm -3, 3-5, and 5 m/s. Since the second and third classes together consist of less than 6 percent of the subset and, hence, only about 1 percent of the total data set, they were excluded from further consideration. Data in class one were then classified by mixing depth to form six scenarios, as follows: 0-300, 301-450, 451-600, 601-800, 801-1,000 and >1,000 m. Representative example dates for each such scenario were then chosen from the data. This information, along with that yielding the frequency of occurrence of each such scenario for the data subset, is provided in Table 5.

TABLE 5. METEOROLOGICAL SCENARIOS SELECTED FOR THE LAS VEGAS VALLEY

Scenario	Wind Speed Range (m/s)	Mixing Depth Range	Frequency of Occurrence	Representative Data
I-1	$0 < U < 3$	$H < 300$	0.081	December 1, 1964
I-2	$0 < U < 3$	$300 < H < 450$	0.106	November 24, 1964
I-3	$0 < U < 3$	$450 < H < 600$	0.431	November 5, 1962
I-4	$0 < U < 3$	$600 < H < 800$	0.203	December 13, 1960
I-5	$0 < U < 3$	$800 < H < 1000$	0.065	November 3, 1961
I-6	$0 < U < 3$	$1000 < H$	0.057	November 28, 1961
II	$3 < U < 5$	--	0.024	January 27, 1961
III	$5 < U$	--	0.033	January 9, 1962

EXERCISE OF SITING METHODOLOGY

For each given meteorological scenario, the APSM was exercised to provide a corresponding set of air quality patterns or scenarios. These air quality patterns were used to compute Figures of Merit which form the basis for the selection of monitoring sites.

Information on the following was required for operation of the APSM for each of the chosen scenarios: near-surface temperature, initial and boundary CO concentrations, atmospheric stability, mixing depth, and near-surface wind speed and direction fields.

Mixing depths for daylight hours of each scenario were computed using hourly near-surface temperatures and the 0400 LST upper air sounding taken by NWS at McCarran International Airport for the dates shown in Table 5. The technique utilized was developed by Holzworth (1964) and consists of extending a dry, adiabatic lapse-rate line from the surface temperature to the 0400 temperature sounding on a thermodynamic chart. The height of the intersection is the mixing depth. The resulting diurnal curves were modified for the nocturnal and late afternoon periods as discussed in Section IV.

Near surface wind data for the example scenario dates existed for two locations in the valley: Nellis Air Force Base and McCarran International

Airport. It was not feasible to develop wind fields for the modeling region using the objective interpolation in the APSM from only two data points at the low wind speeds of the scenarios. For such wind speeds, it is likely that local topographically and thermally induced circulations predominate with a lesser influence provided by the existing synoptic scale pressure gradient. These local circulations are not readily quantifiable without extensive additional field measurements. Thus, an objective wind field model or meteorological simulation model using the topographical information and wind field data from the routine sampling program will be required to develop an adequate wind field from the few data points in the historical data base. Since such models were not available to the project, it was necessary to use the existing wind field from the validation date for which the local topographically and thermally induced circulations appeared to be the most pronounced and apply this for all scenario runs. The date chosen was December 3, 1975. With this restriction, the credibility is diminished for any network design developed using the chosen scenarios. The present work at least represents a quantitative example of the application of the network design methodology for a realistic situation for a location such as the Las Vegas Valley.

Near-surface temperature data for quantifying the CO emissions from certain motor vehicle sources and exposure classes for determination of the vertical eddy diffusivities were both taken from the December 3, 1975, data base. Neither was considered to represent a severe restriction in relation to that imposed by the near-surface wind field utilized. For the nearly clear sky and light wind situations that typically exist for the scenarios, a very similar diurnal temperature curve occurs. The range of temperatures reasonably expected under such conditions for the local CO season is too small to exhibit a substantial effect on the calculated emissions inventory. The range of expected exposure classes for such conditions is likewise too small to significantly alter the calculated values of the diffusivities. It should be noted that the above data could have been obtained from hourly weather observations made by the NWS at McCarran Airport for each of the example scenario dates.

Background and initial CO concentration data used were those developed for the December 3 intensive date. The results of the intensive field program and the model validation studies indicated that background concentration would not have a major impact on the local CO concentration field. These same studies show that the initial CO fields have a significant impact only for the first 2 or 3 hours of simulation. Another approach for model initialization would have consisted of using average CO fields for intensive days or for representative routine sampling dates. The potential impact of the initial CO data field could, of course, be diminished by choosing an earlier diurnal starting time for initiating the simulations.

RESULTS AND DISCUSSION

The APSM was exercised for each of the above described cases. The predicted hour-by-hour CO concentrations for each grid point were then used to compute Figures of Merit. Based on maximum 1-hour CO concentrations, the following was computed:

$$F_1(i,j) = \sum_{\ell=1}^{6} \begin{pmatrix} \text{Frequency of Occurrence} \\ \text{of Meteorological} \\ \text{Pattern } \ell \end{pmatrix} \cdot \begin{pmatrix} \text{Maximum 1-hour surface} \\ \text{CO concentration at Grid} \\ \text{Point i, j under Pattern } \ell \end{pmatrix} \quad (10)$$

Isopleths of these Figures of Merit are plotted in Figure 16.

It should be noted that the Figure of Merit calculation is a mathematical expression of the concept of overlapping isopleth maps in order to locate high frequency-high concentration coordinates as described earlier (Liu et al., 1977). However, use of equation (10) in lieu of actual overlapping of isopleth maps may give rise to the situation where the maximum concentration location is not always selected as the prime location for a station since there is a frequency factor which must be considered. The network designer must be aware of this possibility and make adjustments as appear appropriate. Such adjustments should be subject to a set of rational criteria in order to maintain the universality of application built into the methodology.

As a part of the siting methodology, a computer program was written that searches for the highest values of the Figure of Merit. The number of locations is arbitrary. The program then eliminates locations with high Figures of Merit that are adjacent to locations with higher Figures of Merit without an intervening trough. Such locations are considered to be adequately represented by the adjacent location with the highest value of the Figure of Merit. The isolated peaks of the Figure of Merit thus selected are chosen as potential candidates for monitoring stations. The locations are ranked alphabetically according to the order of importance based upon the computed Figure of Merit. The nine locations that rank highest are plotted in Figure 17 along with the locations of the nine existing CO monitors in the Las Vegas Valley.

A different set of Figures of Merit can be calculated based on the 8-hour average CO concentrations. This was done for both the morning period and the evening period (Figures 18 and 19). A comparison of the locations selected based on maximum 1-hour average CO concentrations with those based on 8-hour evening averages (hours 1200 to 1900 LST) shows that the first three locations are identical and the remainder are shifted only slightly. The locations selected based on the 8-hour evening averages are quite similar to those based on the 8-hour morning averages (hours 0500 to 1200 LST). The location of the first station is the same for both cases, but the second one is located at the southern end of the Las Vegas Strip based on the evening averages, and in the vicinity of Henderson based on the morning averages. It seems that the siting methodology developed under the present project can detect subtle diurnal variations in the emissions pattern which is unique for the Las Vegas area.

The calculation of the Figure of Merit has also been considered for running 8-hour averages rather than the 8-hour periods centered around the morning and evening traffic peaks. Although this was not done, the result can be explained qualitatively on the basis of the concentration distributions

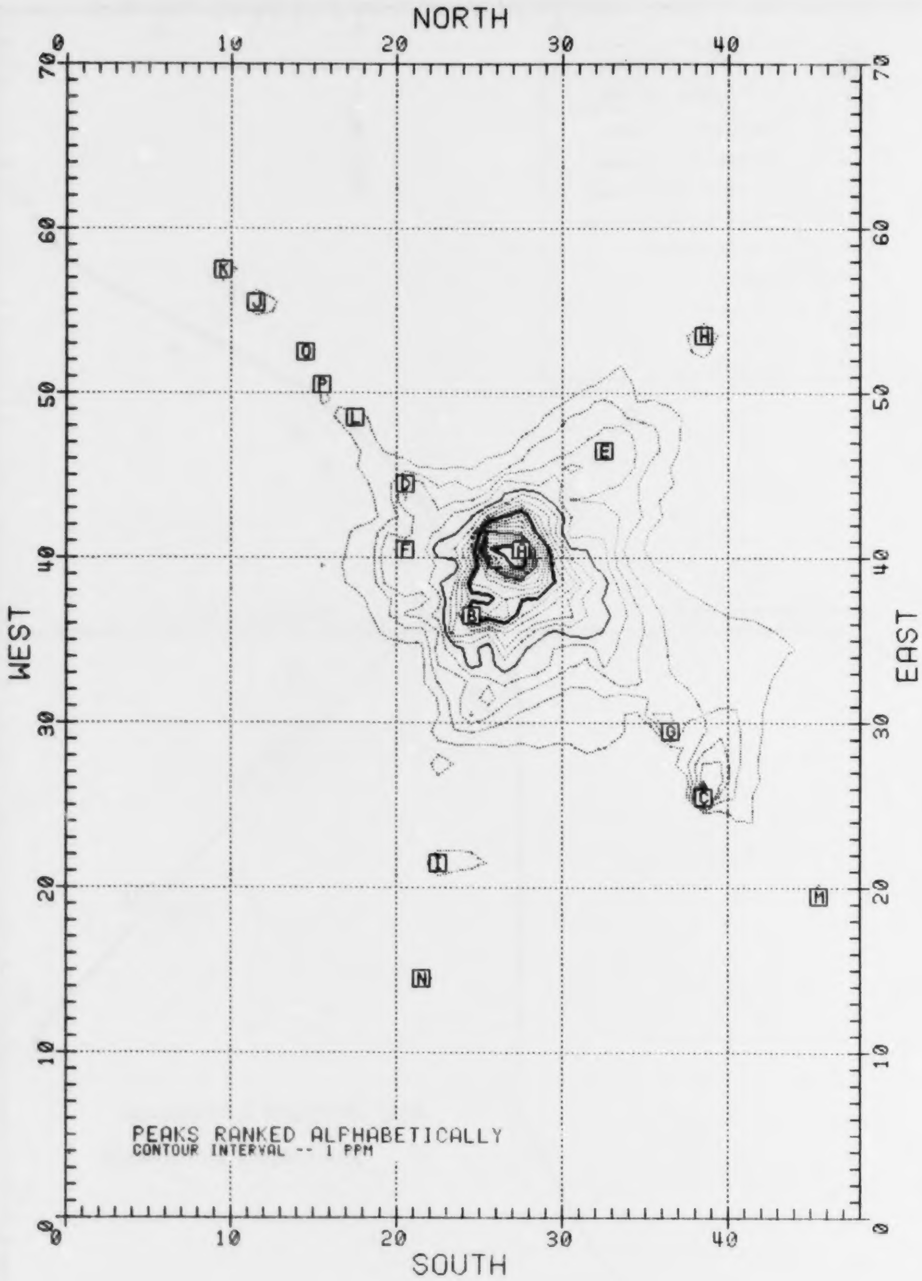

NORTH
SOUTH
WEST
EAST
0
10
20
30
40
50
60
70
K
J
O
P
L
H
E
D
F
A
B
G
C
I
M
N
PEAKS RANKED ALPHABETICALLY
CONTOUR INTERVAL -- 1 PPM

Figure 16. Isopleths of Figures of Merit based on maximum 1-hour average CO concentrations in the Las Vegas Valley

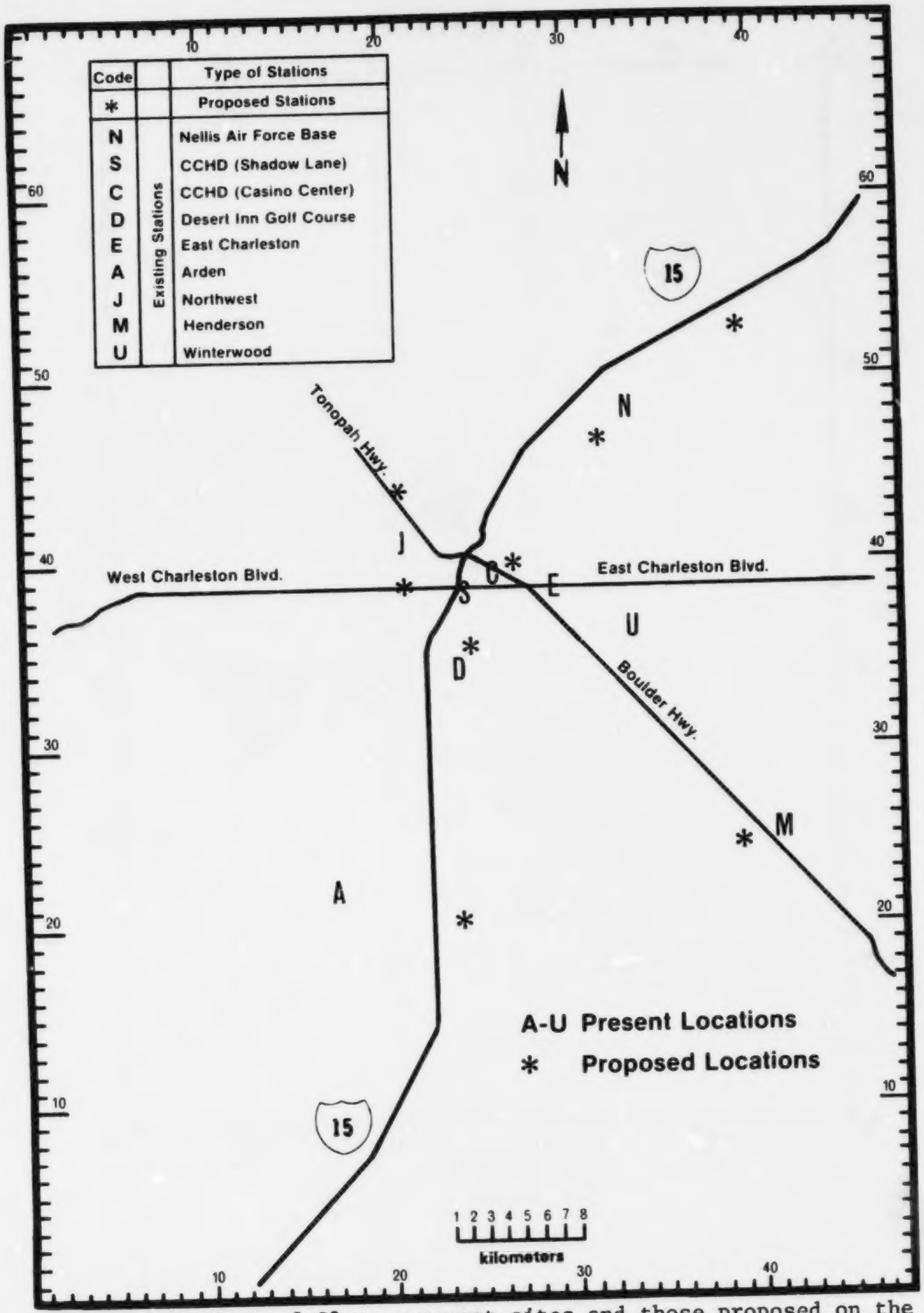

Code
Type of Stations
*
Proposed Stations
Existing Stations
N Nellis Air Force Base
S CCHD (Shadow Lane)
C CCHD (Casino Center)
D Desert Inn Golf Course
E East Charleston
A Arden
J Northwest
M Henderson
U Winterwood
N
15
Tonopah Hwy.
West Charleston Blvd.
East Charleston Blvd.
Boulder Hwy.
J
S
C
E
U
D
N
M
A
A-U Present Locations
* Proposed Locations
1 2 3 4 5 6 7 8
kilometers
10
20
30
40
60
50
40
30
20
10

Figure 17. Locations of CO measurement sites and those proposed on the basis of maximum 1-hour average CO concentrations

produced in the validation and scenario runs. During the late morning and midday hours--from approximately 1000 to 1500 LST--CO concentrations are very low and the spatial distribution is nearly uniform. On the other hand, as seen in the concentration isopleth data in Appendix C, at the periods of peak traffic the concentrations become high and the distribution of pollutants becomes very inhomogeneous. Hence, a running average which included the period from approximately 1000 to 1500 would tend to distribute the Figures of Merit more uniformly than an average taken around the period of peak traffic. However, since the concentrations are much higher during the peak traffic periods, it is expected that locations of stations selected on the basis of the Figure of Merit would not change significantly provided the period of peak concentrations is included in the running average.

It should be noted that the Figure of Merit does not yield an optimum solution in a rigorous mathematical sense. That is, the derivative of an objective function subject to specified constraints is not maximized or minimized. However, the procedure is similar to this strict mathematical one in that it searches out maximum values of a well-defined function. The locations of these values are then prioritized in descending order as potential monitoring sites for the stated purpose of detection of violations of the NAAQS.

The exercise described here optimizes the existing network with respect to siting the stations. The question still arises about the optimum number of stations: is it nine, eight, or ten? In order to approach this question rationally, the cost and the associated benefit of a unit of monitoring information must be evaluated. A comparison must then be made of the cost/benefit ratios resulting from the addition or deletion of a station. The optimum number of stations--optimum with respect to cost/benefit ratio--would be that number of stations which gives the smallest non-zero value of the cost/benefit ratio.

A second constraint might be to optimize the network such that the data retrieved reproduces pollutant isopleths to within some predetermined level of error at a specified confidence interval. Then, by application of advanced statistical procedures, one may determine the number of data points (monitoring sites) required to generate a surface (pollution isopleths) of known accuracy with known or predetermined error limits.

The important point is that a system may be optimized with respect to many potential constraints and that it is incumbent upon the network designer to carefully define those constraints and to assure that they are compatible with the network objectives prior to any network design effort.

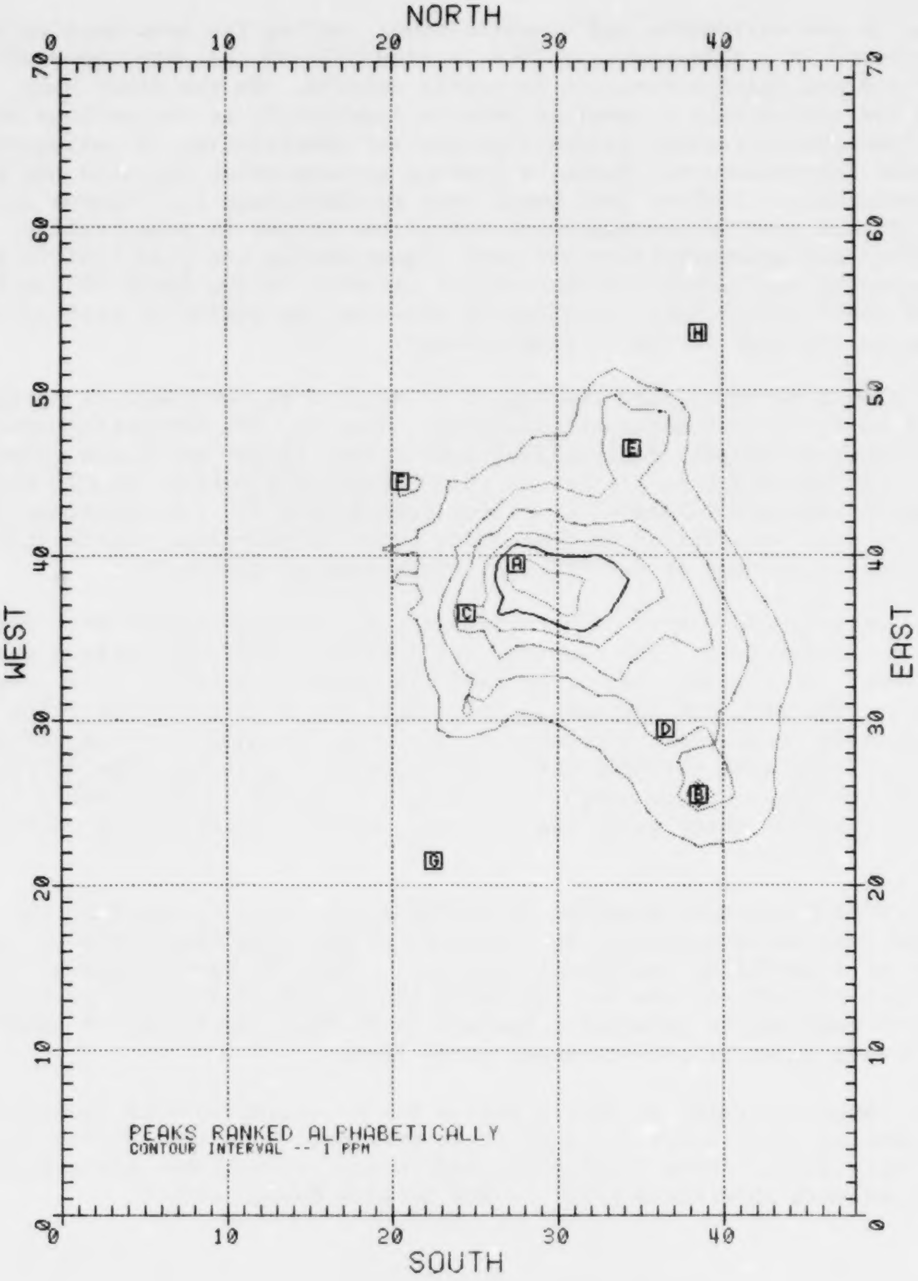

NORTH
SOUTH
WEST
EAST
0
10
20
30
40
50
60
70
A
B
C
D
E
F
G
H
PEAKS RANKED ALPHABETICALLY
CONTOUR INTERVAL -- 1 PPM

Figure 18. Isopleths of Figures of Merit based on morning (0500 to 1200 LST) 8-hour average CO concentration in the Las Vegas Valley

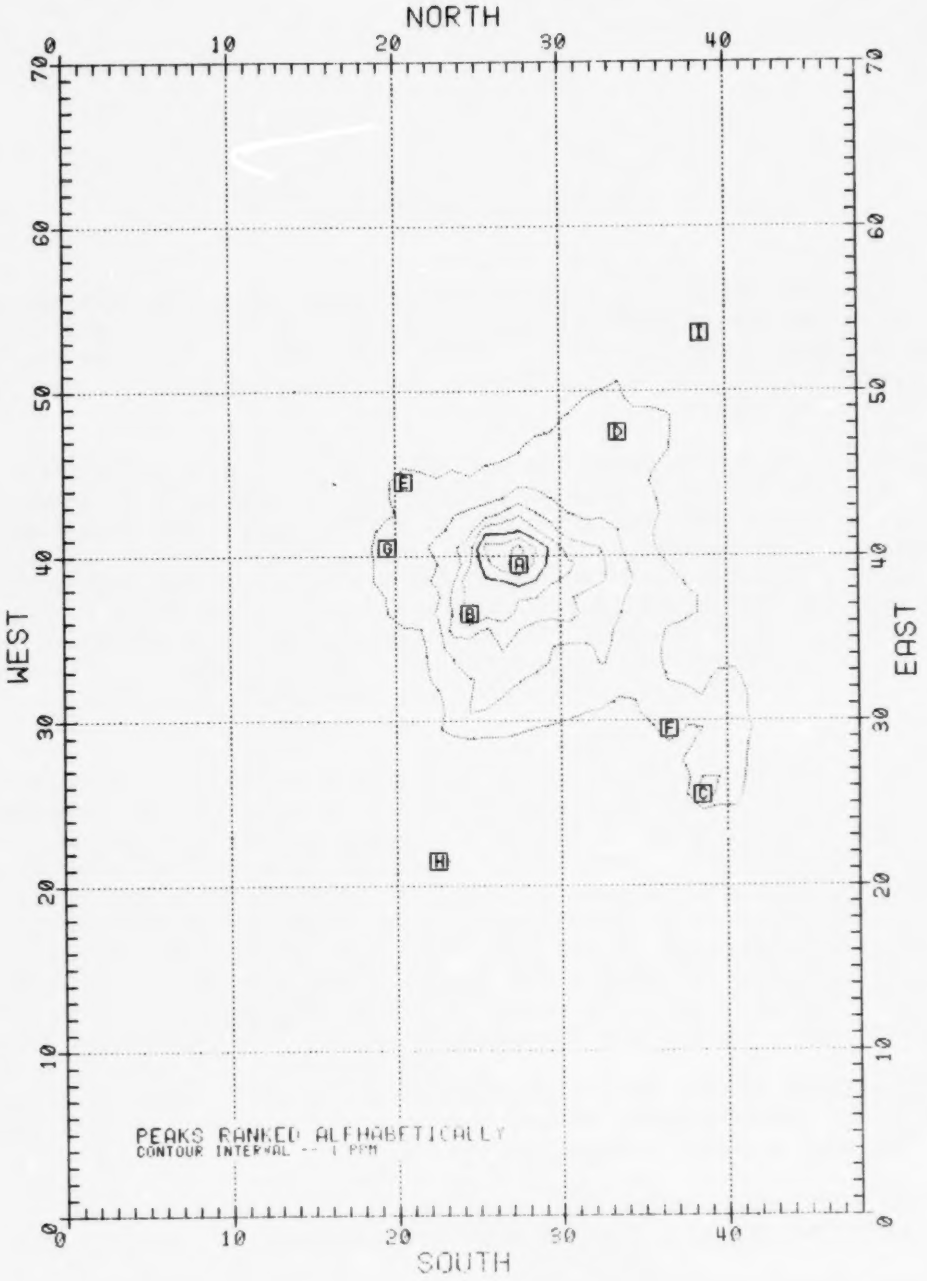

NORTH
0
10
20
30
40
70
60
50
40
30
20
10
0
WEST
EAST
I
D
E
G
A
B
F
C
H
PEAKS RANKED ALPHABETICALLY
CONTOUR INTERVAL -- 1 PPM
SOUTH

Figure 19. Isopleths of Figures of Merit based on evening (1200 to 1900 LST) 8-hour average CO concentration in the Las Vegas Valley

VI CONCLUDING REMARKS

An objective method that uses aerometric data and a mesoscale air quality simulation model was proposed for selecting sites for pollutant monitoring networks in urban areas (Liu et al., 1976). This report discusses that method and its applicability and potential as a planning tool, using the Las Vegas Valley as a test region.

An advantage of this method is not only that it avoids subjectivity in the choice of monitoring locations but also that it offers an optimum network configuration for a given set of criteria. Furthermore, objective methods are very flexible. For example, if a weather forecast is available, an objective method such as the one described herein can be used to locate monitoring sites that accommodate future anticipated emission distribution patterns. The utility of the method is by no means limited to the design of a new monitoring network. It should also be useful for the modification (through addition or relocation of stations) of an existing network that has known deficiencies (e.g., Goldstein, 1976).

The application of the method is not limited to the test area (Las Vegas Valley). The use of local parameters as model inputs and locally measured data for model verification is possible in order to apply the method to a different city or locale. Depending on available resources and the specific situation, the model may be more or less fine-tuned to the specific area for more accurate predictions. Costs involved in the application of the method will vary widely depending on the amount and quality of data available. For example, if long-term aerometric data from a dense network are available, one might even consider eliminating the model validation steps by generating pollutant distributions and their frequencies strictly from historical data.

The validity of the results obtained by the proposed method necessarily depends on the reasonableness of many hypotheses or assumptions that are invoked. The most critical assumptions are that

- the air quality model used simulates pollutant concentration distributions in a reasonably accurate manner;
- the chosen scenarios are representative of the meteorological conditions during which high pollutant concentrations occur;
- the criteria for locating the monitoring sites are appropriate.

These assumptions are believed to be valid for the application presented in this report.

REFERENCES

Ames, J., J. D. Reynolds, D. C. Whitney, and N. T. Fisher. 1978. User's Guide to the SAI Photochemical Air Pollution Simulation Program. Final report on Contract 68-03-2399, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Behar, J. V., L. M. Dunn, J. L. McElroy, R. R. Kinnison, and P. N. Lem. 1976. Development of Criteria for Establishing Guidelines for Optimization of Environmental Monitoring Networks: Air Monitoring Networks. In: Proceedings of the International Conference on Environmental Sensing and Assessment, 20-1.

Darby, W. P., P. J. Ossenbruggen, and C. J. Gregory. 1974. Optimization of Urban Air Monitoring Networks. Journal Environmental Engineering Division (American Society Civil Engineering), EE3, pp. 577-591.

Goldstein, I. F. 1976. Use of Aerometric Network Data to Monitor Acute Health Effects. Paper No. 76-32.6, 69th Annual Meeting of the Air Pollution Control Association, Portland, Oregon.

Hoel, P. G. 1962. Introduction of Mathematical Statistics (Third Edition). John Wiley and Sons, Inc., New York, 427.

Holzworth, G. C. 1962. A Study of Air Pollution Potential for the Western United States. Journal of Applied Meteorology, Vol. 1, No. 2, pp.366-382.

Holzworth, G. C. 1964. Estimates of Mean Maximum Mixing Depths in Contiguous United States. Monthly Weather Review, Vol. 92, No. 5, pp. 235-242.

Holzworth, G. C. 1974. Meteorological Episodes of Slowest Dilution in Contiguous United States. EPA-650/4-74-002, U.S. Environmental Protection Agency.

Johnson, W. B., F. L. Ludwig, N. F. Dabberdt, and R. J. Allen. 1973. An Urban Diffusion Model for Carbon Monoxide. Journal of Air Pollution Control Association, Vol. 23, pp. 490-498.

Koch, R. C., and S. D. Thayer. 1972. Validity of The Multiple Source Gaussian Plume Urban Diffusion Model Using Hourly Inputs of Data. In: Proceedings of Conference on Urban Environment and Second Conference on Biometeorology, Philadelphia, Pennsylvania, October 31-November 2; p. 64-68.

Lettau, H. H. 1969, Note on Aero-Dynamic Roughness - Parameter Estimation on the Basis of Roughness - Element Description. Journal of Applied Meteorology, Vol. 8, pp. 828-832.

Liu, M. K. 1973. Further Development and Evaluation of a Simulation Model for Estimating Ground-Level Concentrations of Photochemical Pollutants. Vol. III. Automation of Meteorological and Air Quality Data for the SAI Urban Airshed Model. Report R73-SAI-32, Systems Applications, Inc., San Rafael, California 94903.

Liu, M. K., D. C. Whitney, and P. M. Roth. 1976a. Effects of Atmospheric Parameters on the Concentration of Photochemical Air Pollutants. Journal of Applied Meteorology, Vol. 15, pp. 829-835.

Liu, M. K., D. C. Whitney, J. H. Seinfeld, and P. M. Roth. 1976b. Continued Research in Mesoscale Air Pollution Simulation Modeling, Vol. I. Assessment of Prior Model Evaluation Studies and Analysis of Model Validity and Sensitivity. EPA-600/4-76-016A.

Liu, M. K., J. P. Meyer, R. I. Pollack, P. M. Roth, J. H. Seinfield, J. V. Behar, L. M. Dunn, J. L. McElroy, P. N. Lem, A. M. Pitchford, and N. T. Fisher. 1977. Development of a Methodology for the Design of a Carbon Monoxide Monitoring Network. EPA-600/4-77-019. U.S. Environmental Protection Agency.

Lund, I. A. 1963. Map-Pattern Classification by Statistical Techniques. Journal of Applied Meteorology, Vol. 2, pp. 56-65.

McCormick, R. A. 1968. Air Pollution Climatology. Air Pollution; A. C. Stern, editor, Academic Press, New York, New York.

Meyers, J. P. 1971. Discriminant Analysis in Laterite and Lateritic Soils and Other Problem Soils of Africa. An engineering study for Agency for International Development. AID/csd-2164. June.

Morgan, G. B., G. Ozolins, and E. C. Tabor. 1970. Air Pollution Surveillance Systems. Science, Vol. 170, p. 289.

Olsson, L. E., and S. Ring. 1974. Validation of Urban Air Pollution Models. In: Proceedings of 5th Meeting NATO/CCMS Expert Panel on Air Pollution Modeling, Roskilde, Denmark, June 4-6; Chapter 25.

Ranzieri, A. J., and C. E. Ward. 1975. Caline Z - An Improved Microscale Model for the Diffusion of Pollutants From a Line Source. Air Quality Workshop, Washington, D.C.

Reynolds, S. D., P. M. Roth, and J. H. Seinfeld. 1973. Mathematical Modeling of Photochemical Air Pollution--I: Formulation of the Model. Atmospheric Environment, Vol. 7, pp. 1033-1061.

Reynolds, S. D., P. M. Roth, and J. H. Seinfeld. 1974. Mathematical Modeling of Photochemical Air Pollution--III: Evaluation of the Model. Atmospheric Environment, Vol. 8, pp. 563-596.

Roach, G. E., and A. E. MacDonald. 1975. Map-Type Precipitation Probabilities for the Western Region. U.S. Department of Commerce, NOAA, NWS, Com-75-10428.

Roth, P. M., P. J. W. Roberts, M. K. Liu, S. D. Reynolds, and J. H. Seinfeld. 1974. Mathematical Modeling of Photochemical Air Pollution--II. A Model and Inventory of Pollutant Emissions. Atmospheric Environment, Vol. 8, No. 2, pp. 97-130.

Schuck, E. A., and R. A. Papetti. 1973. Examination of the Photochemical Air Pollution Problem in the Southern California Area. Appendix D of Technical Support Document for the Metropolitan Los Angeles Intrastate Air Quality Control Region Transportation Control Plan Final Promulgation, Region IX, U.S. Environmental Protection Agency, San Francisco, California.

Seinfeld, J. H. 1972. Optimal Location of Pollutant Monitoring Stations in an Airshed. Atmospheric Environment, Vol. 6, pp. 847-858.

Shirr, C. C., and L. J. Shieh. 1974. A Generalized Urban Air Pollution Model and Its Application to the Study of SO_2 Distributions in the St. Louis Metropolitan Area. Journal of Applied Meteorology, Vol. 13, pp. 185-203.

Simmons, W. 1974. Comments on Modeler User Conference. In: Proceedings of 5th Meeting NATO/CCMS Expert Panel on Air Pollution Modeling, Roskilde, Denmark, June 4-6; Chapter 40.

Slater, H. H., and J. A. Tikvart. 1974. Application of a Multiple-Source Urban Model. In: Proceedings of 5th Meeting NATO/CCMS Expert Panel on Air Pollution Modeling. Roskilde, Denmark, June 4-6; Chapter 14.

U.S. Environmental Protection Agency. 1976. Compilation of Air Pollutant Emissions Factors, AP-42, and Supplements 1 through 5, Second Edition.

APPENDIX A
FIELD PROGRAM INSTRUMENTATION

Routine and special sampling of aerometric parameters was accomplished in the Las Vegas Valley to provide data for model verification and supplementary data used in the design of a CO-monitoring network. Details of equipment utilized, data collection and reduction, and quality assurance established for the field program are presented in this appendix.

EQUIPMENT

The total monitoring network in the Las Vegas Valley was composed of 25 stations operated cooperatively by the CCHD, the NDH, and the EPA. In addition, wind speed, wind direction, and temperature data from NWS at McCarran International Airport were utilized. Continuous measurements of CO were made at nine stations (Figure 3). The instruments used in making these measurements are

- Beckman Model 6800 gas chromatograph (GC)
- Bendix Model 8501-5BA non-dispersive infrared (NDIR) analyzer
- Beckman Model 7000 dual isotope fluorescence (DIF) analyzer
- Energetic Science "Ecolyzer"

Continuous wind speed, wind direction, and air temperature measurements were made at 13 sites in the network using Meteorology Research Inc. (MRI) Models 1072 and 1022 weather stations. In addition, near-surface air temperatures were monitored at 4 sites using a Belfort Instrument Company Hygrothermograph, Model 594 (Figure 4).

Measurements of winds aloft were made at two sites (Figure 4) during intensive measurement periods with single theodolite observations of standard 20-gram helium-filled pilot balloons (pibal). Elevation and azimuth angles at nominal 30-second intervals are read to the nearest 0.1°.

Low altitude aerometric monitoring (spirals) over the Las Vegas Valley was performed during intensive periods from a Sikorsky S-58 helicopter operated by the EPA. Air temperature and dew point were measured using a Cambridge System Model CS-137 (CO data were collected but unusable due to instrument malfunction). Four flights were conducted on each intensive sampling day: sunrise to 1 to 2 hours after sunrise, mid-morning, mid-afternoon, and 1 hour before sunset to 1 to 2 hours after sunset. Locations of helicopter spirals are shown in Figure A-1.

All data with the exception of those for pibals and the helicopter were recorded as analog signals on strip charts. Pibal data were recorded manually

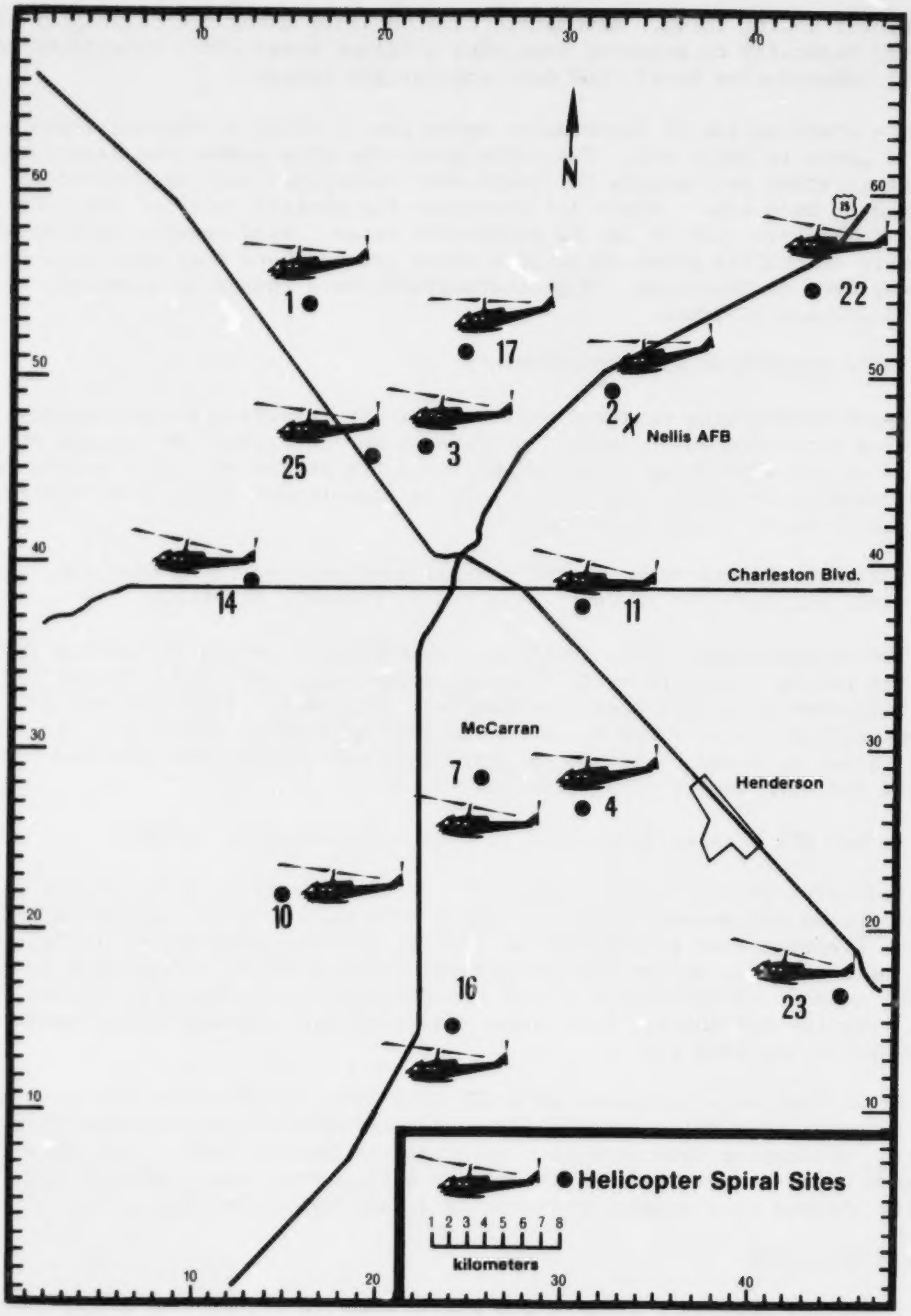

N
15
1
17
22
2
Nellis AFB
25
3
14
Charleston Blvd.
11
McCarran
7
4
Henderson
10
16
23
Helicopter Spiral Sites
1 2 3 4 5 6 7 8
kilometers
10
20
30
40
50
60

Figure A-1. Helicopter spiral sites in the Las Vegas Valley on computer coding forms. Aerometric data obtained using the helicopter were recorded digitally on magnetic tape with a Cipher Model 70M-7 interfaced to a Monitor Laboratories Model 7200 data acquisition system.

The distribution of instruments among the 25 sites in the Las Vegas network is given in Table A-1. The table gives the site number and description, the organization responsible for instrument operation, and the parameters measured at each site. Table A-2 describes the general land use characteristics in the vicinity of the CO monitoring sites. Wind sensors were mounted on towers or utility poles about 10 m above ground where they were well-exposed and away from obstructions. Hygrothermographs were housed in standard, louvered Stevenson shelters.

FIELD DATA COLLECTION AND REDUCTION

Hygrothermographs measured near-surface air temperature continuously. Data were retrieved once a week. At site 6, one instrument was placed on the roof of an air monitoring trailer, and the other on the roof of a nearby four-story building in order that differences in temperature could be estimated over the 12-meter change in height.

Strip chart data from the MRI weather stations recording wind run, wind direction, and temperature were collected at biweekly intervals.

The CO instruments made continuous measurements during the entire field sampling period. Data from the Ecolyzer instruments (sites 19, 20 and 21) were collected at either weekly or biweekly intervals. That from the NDH gas chromatographs (sites 2 and 10) were obtained at 1-month intervals. At CCHD sites (sites 5, 6 and 9) the strip chart data were collected daily and usually reduced the same day by CCHD personnel.

At one EPA trailer (site 18), CO data were collected weekly.

Reduction of field data charts from aerometric stations for preparation of data bases was accomplished on a Hewlett-Packard 9830 calculator and digitizer. Preprocessing procedures for CO data included digitizing initial and final zero and span values for the determination of drift corrections to be applied to each of the sample points and corrections to span gas changes over time. For the MRI charts, wind speed was determined through measurement of the slope of the wind run.

Pibal data were processed on a CDC 6400 using an algorithm based on standard trigonometric relationships and a standard rate of balloon rise from NWS tables. Helicopter data were also processed on the CDC 6400. Data were first screened, then converted from voltages to engineering units, edited, and finally plotted as a single parameter as a function of height.

QUALITY ASSURANCE

A quality assurance program was established to ensure that measurements within the individual programs were comparable and that the data handling was as error-free as possible. Methods to achieve this are described below.

TABLE A-1. DATA COLLECTING SITES - LAS VEGAS VALLEY
WINTER 1975 - 1976

LOCATION	OPERATOR	PARAMETERS	EQUIPMENT	HELI-COPTER SPIRALS
1. Tule - Wild Animal Reserve (extreme N.W.)	EPA	WS, WD, T	MRI #1072	X
2. Nellis Air Force Base	NDH	CO, WS, WD	Beckman 6800 GC, MRI #1072	X
3. Fire Station #3 - NLV	EPA	WS, WD, T, Pibal	Theodolite MRI #1072	X
4. Pump Station 2, Henderson	CCHD	WS, WD, T	MRI #1072	X
5. CCHD - Shadow Lane	CCHD, EPA	CO	Bendix NDIR #8501-5BA	
6. CCHD - Casino Center	CCHD, EPA	CO	Bendix NDIR	
" " "	" "	T	Belford #594 (2)	
7. McCarran Airport	EPA, NWS	T, WS, T	Belford #594	X
8. Rob's - S.E. of Henderson	EPA	WS, WD, T	MRI #1072	
9. CCHD - E. Charleston	CCHD	CO	Beckman 7000 DIF	
10. Arden (extreme S.W.)	NDH	CO, WS, WD	Beckman 6800 GC, MRI #1072	X
11. Regency - Nellis & E.Charleston	EPA	WS, WD, T	MRI #1072	X
12. Leisure World-Desert Inn and Eastern	EPA	WS, WD, T	MRI #1072	
13. Cemetery - Paradise Valley	EPA	WS, WD, T	MRI #1072	
14. W. Charleston	EPA	WS, WD, T	MRI #1072	X
15. Jade Park	EPA	WS, WD, T	MRI #1072	
16. Sky Harbor Airport	EPA	WS, WD, T	MRI #1072	X
17. N. 5th & Regina	EPA	WS, WD, T	MRI #1072	X
18. D.I. Golf Course	EPA	CO	Beckman 7000 DIF	
19. Private residence (N.W.)	EPA	CO	Ecolyzer	
20. Private residence (Henderson)	EPA	CO	Ecolyzer	
21. Private residence (Winterwood golf course)	EPA	CO	Ecolyzer	
22. Apex (extreme N.E.)	EPA	-	--	X
23. R.R. Pass (extreme S.E.)	EPA	-	--	X
24. UNLV	EPA	Pibal	Theodolite	
25. NLV Air Terminal	EPA	T	Belford #594	X

WS - wind speed; WD - wind direction; T - temperature; CO - carbon monoxide
X - parameters measured with helicopter spirals are T, dew point and altitude

TABLE A-2. LAND USE CHARACTERISTICS IN THE VICINITY OF THE CO MONITORING SITES

Site No.	Site	
2	Nellis AFB	Trailer in vacant lot 2 km from major streets/highways. Scattered storage and training facilities 0.4 km to N and S, fuel storage facility 1 km to NE, and runways 2.5 km to E.
5	CCHD Shadow Lane	CCHD office building surrounded by large parking lot in residential/commercial area with nearest major streets 0.75 km to W, 1 km to S and 0.5 km to E.
6	Casino Center	Trailer in edge of parking lot adjoining alley in downtown commercial area. Nearby structures 1 to 2 stories except for 4-story building 0.1 km to E. Nearest street 0.05 km to S.
9	East Charleston	Trailer in construction yard bordering alley adjacent to a small shopping center and parking lot bordering on a major street 0.1 km S. Area is mixed commercial/residential with large shopping center 0.5 km to S and other major streets 0.5 km to W and SW.
10	Arden	Trailer in fenced area adjacent to office building for local civil defense agency. Surroundings open desert except for office building and scattered structures along railroad 0.25 km to E. Nearest major road 1 km to N.
18	D. I. Golf Course	Trailer adjacent to tennis courts in center of a large golf course. Nearest major street is 0.25 km to S with the Las Vegas Strip 0.5 km to W, other major streets 0.5 km to N and E and major hotel 0.25 km to NW.
19	Private Residence	Storage shed in the backyard of a home in a residential area. Nearest major street is 0.2 km to S with other major streets 0.5 km and 1 km from the site.
20	Private Residence	House in a residential area of Henderson. Nearest major street 0.4 km to N. Open desert beyond 0.5 km to E.
21	Private Residence	Home bordering a golf course in residential area. Nearest major streets are 0.3 km to the N and 0.8 km to W.

Uniformity in air quality measurements was attained through calibration of span gases against National Bureau of Standards (NBS) standard reference gas. EPA and NDH span gases were calibrated against the same NBS standard by the EPA while the CCHD used its own NBS standard reference. Cross references were acquired through a single EPA cylinder of known concentration passed as a blind sample to each agency.

Routine and preventive maintenance and frequent instrument calibrations were also carried out by each agency. The EPA used the following procedures.

- Standardized checklists and log books were kept for all instrumentation. (Instrument recorder charts were labeled at each calibration with site name, span value, time, and date.)
- For pilot balloon measurements, a standard alignment reference point was determined for each site, and used by all technicians.
- Mechanical weather stations were serviced routinely every 2 weeks. At this time, the station's alignment with true north was verified using predetermined reference points.
- Ecolyzer CO analyzers were calibrated (i.e., set to zero and spanned) and inspected for maintenance purposes every 12 or 24 hours depending on the particular instrument's drift characteristics.
- The Beckman 7000 Dual Infrared Fluorescence instrument (site 18) was calibrated every week.
- Hygrothermographs were inspected weekly for maintenance purposes. In addition, each instrument was calibrated in an environmental chamber at various known temperatures.
- Helicopter instruments were calibrated prior to and following each flight.

The NDH followed maintenance and check procedures as follows.

- At each of two trailers, checks were made twice weekly to detect possible instrument malfunction. Additional checks were carried out during intensive study periods.
- The gas chromatograph was set to zero and spanned automatically every midnight.

The CCHD maintained three sites with procedures similar to those used by the NDH. Instruments were set to zero, spanned, and calibrated every second or third day.

APPENDIX B
EMISSIONS INVENTORY FOR THE LAS VEGAS VALLEY

INTRODUCTION

An inventory of emissions from point sources, area sources, and mobile sources, expressed as emissions per hour per grid square, was developed for the Las Vegas Valley for carbon monoxide (CO) for the winter of 1975-1976. These data were adjusted for temperatures specific to the simulation days. Information for assembling the inventory was provided by the local electric power and gas companies, the Nevada Department of Highways (NDH), the Clark County District Health Department (CCHD), and industries in the area of concern. The National Emissions Data System (NEDS) was also interrogated for basic emission sources. Emission factors from the U.S. Environmental Protection Agency (EPA) publication, Compilation of Air Pollutant Emission Factors, 2nd Edition, and its Supplements 1 through 5 (AP-42), were used except as noted.

The inventory encompassed a modeling region of 48 km by 70 km delineated by the ridgelines of the mountains surrounding the Las Vegas Valley. Since much of the Valley is undeveloped, the inventory involved surveys within the occupied areas and the specification of zero emissions in the bordering areas.

GRID

The final non-zero grid for the emissions data is a network of 1-km squares, 48 km by 47 km in size, which is skewed by 1.45° from the Universal Transverse Mercator (UTM) Coordinate System. The UTM zone 7 coordinates of the corners and the definition of the squares are shown in Figure B-1. Point (XY) = (0,0) is at the lower left corner of the grid. The grid squares are numbered 1 to 48 increasing to the east (in the X direction), and numbered 1 to 48 increasing to the north (in the Y direction). A grid square is identified by the distance of its upper right corner in the X and Y directions from the origin. Point locations are assigned to squares by using the integer part of the distance from the point to the origin, and then adding 1 kilometer to the X and Y values. Thus, the lower left square is the square (1,1). This grid aligns exactly with that used by the NDH for 1976 traffic data and for its traffic flow model.

The emissions inventory coordinates (X,Y) and UTM coordinates are related by the following expressions:

$$X_{utm} = (X + 0.66)\cos\alpha - (Y + 11.67)\sin\alpha + 642.0$$

$$Y_{utm} = (X + 0.66)\sin\alpha + (Y + 11.67)\cos\alpha + 3964.0$$

Where: a = 0.025237 radians or 1.445984 degrees.

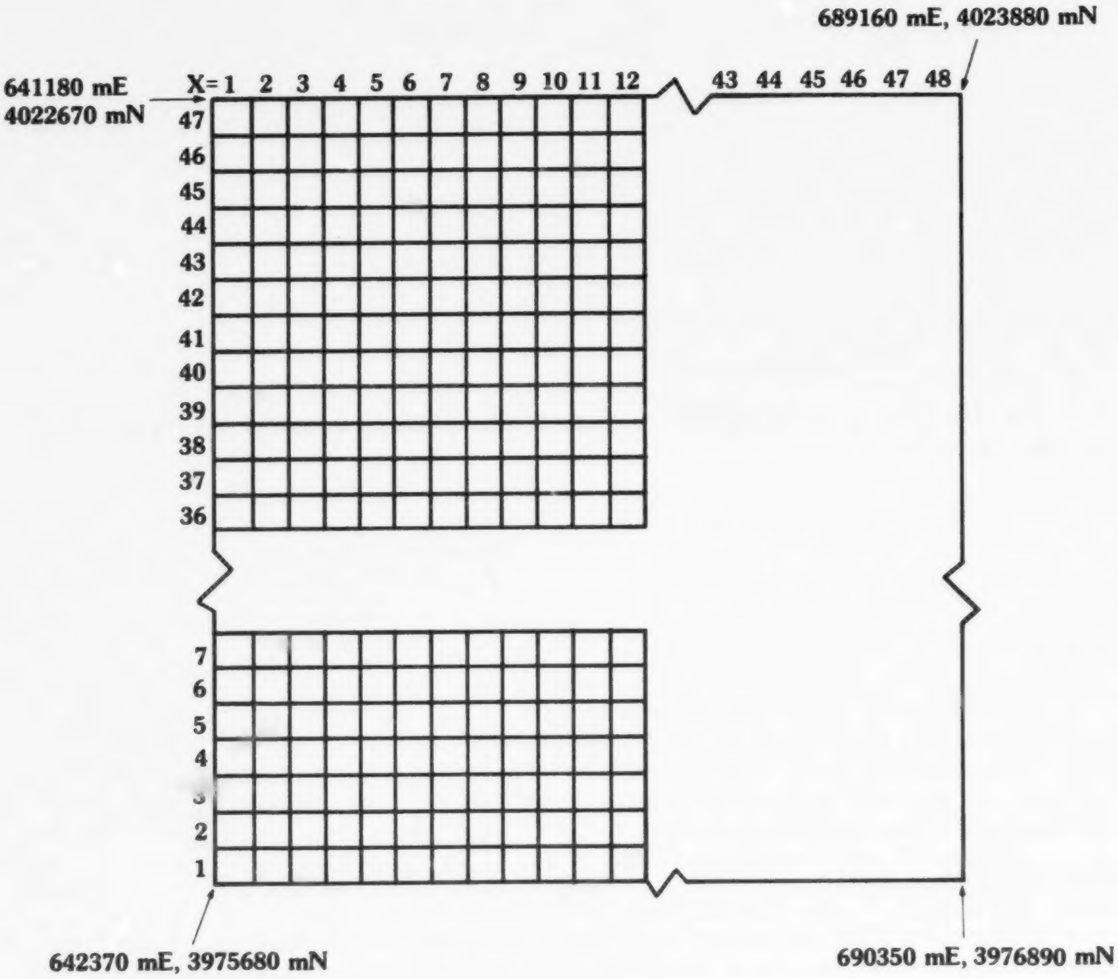

689160 mE, 4023880 mN
641180 mE
4022670 mN
X= 1 2 3 4 5 6 7 8 9 10 11 12
43 44 45 46 47 48
47
46
45
44
43
42
41
40
39
38
37
36
7
6
5
4
3
2
1
642370 mE, 3975680 mN
690350 mE, 3976890 mN

Figure B-1. Emissions inventory grid definition.

Emissions data distributed according to several other grids systems with different origin references were used to develop the inventory. The relationships among these grids are illustrated in Figure B-2. These data were first located using the EPA coordinate system which is parallel to the UTM coordinate system.

To convert EPA coordinates to emission inventory coordinates:

$$X = (X_{epa} - 0.37)\cos\alpha + (Y_{epa} - 11.68)\sin\alpha$$

$$Y = -(X_{epa} - 0.37)\sin\alpha + (Y_{epa} - 11.68)\cos\alpha$$

Where:

$a = 0.025237$ radians or 1.445984 degrees.

To convert EPA coordinates to UTM coordinates:

$$X_{epa} = X_{utm} - 642.0$$

$$Y_{epa} = Y_{utm} - 3964.0$$

Traffic data were supplied by the NDH on a 50-km x 50-km grid paralleling the UTM grid.

$$X_{traffic\ grid} = X_{epa}$$

$$Y_{traffic\ grid} = Y_{epa} + 12$$

SOURCES

The inventory involved the summing of emissions from point, area, and mobile sources, resulting in emissions per hour per grid square. Point sources considered were power plants and industrial manufacturing. Space heating was handled as an area source. Mobile sources considered were aircraft, railroads, and automobile traffic.

Area (Space Heating)

Estimates of CO emissions from space heating were made using fuel flow data obtained from Southwest Gas Company records. These data were hourly averages for the same consecutive 6 days used to estimate power plant emissions. Space heating included all residential and commercial use and was derived from the total gas flow data taking into account electric power plant and industrial use. The consumer distribution figures used were those reported in the Southwest Gas Annual Operating Report for 1975. The distribution figures were applied uniformly through each day throughout the year. Total space-heating emissions were calculated by the following equation:

$$E_{space\ h} = (0.79 \times C_r + 0.21\ C_c) \times G_h$$

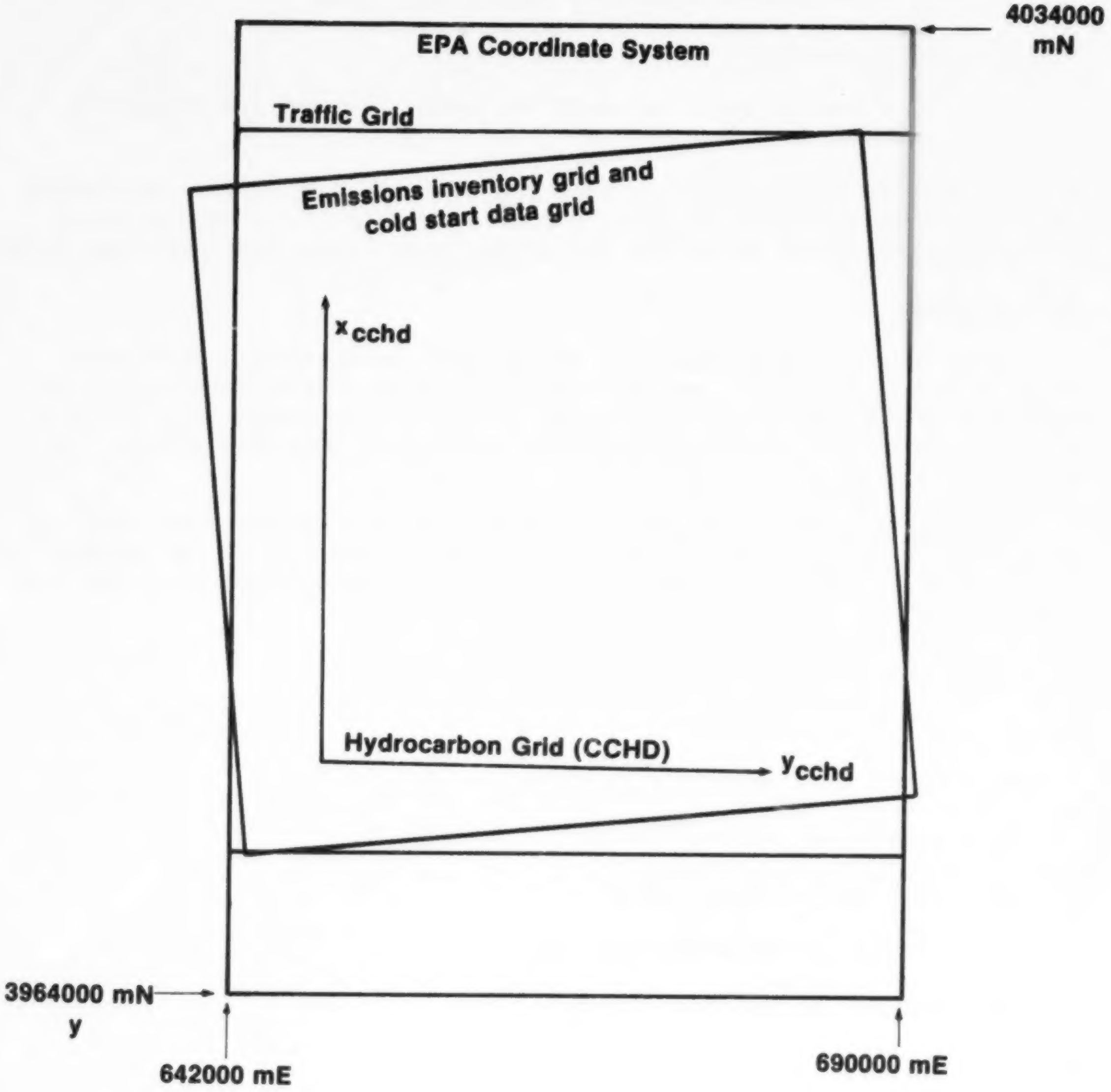

EPA Coordinate System
4034000 mN
Traffic Grid
Emissions inventory grid and cold start data grid
x_{cchd}
Hydrocarbon Grid (CCHD)
y_{cchd}
3964000 mN
y
642000 mE
690000 mE

Figure B-2. Relationship between grid systems for data used in the present study

Where:

$E_{space\ h}$ = emissions from space heating for hour (h)

C_r = residential space heating factor

C_c = commercial space heating factor

G_h = average gas flow excluding power plant and industrial use for hour (h)

The emissions were apportioned to each grid square according to a population distribution in the Valley linearly interpolated from 1970 census data and 1980 projections found in the NDH (1970) Las Vegas Valley Transportation Study.

Point Sources

Point sources are divided into two groups: power plants, which have variable hourly emissions, and the other industrial sources with relatively uniform hourly emissions. Data for the latter were developed from the NEDS annual totals, using the assumption that hourly emissions were uniform over the full year.

Calculations for the Sunrise and Clark Power Plants were made using 6-day averages of fuel flows during January 1975. This period was assumed to be representative of a winter season. Power plant emissions per hour are given by the following equation:

$$E_h = O_h \times FO + G_h \times FG$$

Where:

E_h = power plant emissions in kilograms for hour (h)

O_h = power plant oil flow in pounds for hour (h)

FO = fuel oil emission factor

G_h = average gas flow for hour (h)

FG = natural gas emission factor

Aircraft

Aircraft emissions were calculated for the three main airports in the Valley: McCarran International Airport, North Las Vegas Air Terminal, and Nellis Air Force Base. The majority of data for the former were developed from the Official Airline Guide, North American Edition. This book contains up-to-date airline schedules including flight times, flight numbers, and aircraft used. The number of nonscheduled flights and aircraft types (6) were estimated by Hughes Executive Terminal personnel. Using this information, hourly engine landing and take-off (LTO) cycles were obtained using the following equations:

$$\text{Engine LTO cycles} = \frac{\#\text{operations}}{2} \times \#\text{ engines per aircraft}$$

An operation is an aircraft arrival or departure.

The calculation of total aircraft emissions per hour at McCarran International Airport is given by the equation:

$$E_h = \sum_{i=1}^{6} L_{hi} C_i$$

Parameters for the above equation are defined as follows:

E_{hp} = total aircraft emissions for hour (h)

L_{hi} = the number of engine LTO cycles for hour (h) and aircraft class (i)

C_i = the emission factor in kg/engine LTO cycle for aircraft class (i).

The North Las Vegas Air Terminal is used principally by private aircraft and during daylight hours. Information on the number of flight operations conducted each day were provided by the air traffic controller. These operations were estimated to occur uniformly each day over the year and equally over all daylight hours on any given date.

Total hourly aircraft emissions from McCarran International Airport and North Las Vegas Air Terminal were distributed across grid squares which were covered by the runways of the two airports. The calculation of aircraft emissions per grid square is given by:

$$E_{hXY} = E_h F_{XY}$$

Where:

E_{hXY} - aircraft emissions in kilograms for hour (h) and grid square (XY)

E_h = aircraft emissions from the airport for hour (h)

F_{XY} = fraction of airport runway contained in grid square (XY)

Emissions data, supplied by the U.S. Air Force Environmental Section, were similarly distributed over the grid square encompassing Nellis Air Force Base.

Railroads

An estimate of annual emissions from railroads was taken from Transportation Control Plan Development for Clark County, Nevada (1975).

According to the Union Pacific Trainmaster in Las Vegas, approximately 13 trains pass through Las Vegas per day. Since service is unscheduled, the arrivals and departures of trains are distributed in an unknown pattern. To assign a distribution of these sources in the Valley, the total daily railroad emissions were divided into 13 equal parts and, using a random number generator, they were distributed among the 24 hours of the day. An equal portion of emissions for each train was assigned to each of the 70 grid squares through which the trains pass. The time lag of a train moving from one end of the valley to the other was assumed to be less than 1 hour.

Traffic

Emissions from traffic were developed from actual data for 1974 supplied by the NDH. For each grid square, data are given for roadway types, average speeds, the number of vehicle miles traveled (VMT) and hourly-averaged traffic flow. Cold/hot start information and the percentages of light-duty (LDV) and heavy-duty (HDV) vehicles traveling on the various roadway types are also included. Data for diesel trucks and motorcycles were not available. However, these were shown to contribute less than 3 percent of all CO (TRW, Inc., 1975).

The calculation of HDV emissions is given by:

$$E_{HhXY} = \frac{1}{1000} \left(\frac{\%TRAF_h}{100} \right) \left[\sum_q \left(\frac{\%HDV}{100} (VMT) \sum_{i=63}^{75} c_{in}\, m_{in}\, v_{is} \right) \right]$$

where:

E_{HhXY} = HDV emissions in kilograms for hour (h) and grid square (XY)

$\%TRAF_h$ = percentage of daily traffic for hour (h) as developed from hourly traffic count data

$\%HDV$ = percentage of HDV for roadway type (q)

VMT = the vehicle miles traveled per day for roadway type (q) and grid square (XY)

c_{in} = the 1975 Federal Test Procedure (FTP) mean emission factor for the i-th model year HDV in calendar year (n)

m_{in} = the fraction of annual travel by the i-th model year HDV during calendar year (n)

v_{is} = the speed correction factor for the i-th model year vehicles for average speed (s)

For c_{in} and m_{in}, n = 1975.

LDV emissions require correction for temperature dependence. This correction is included in the following equation:

$$E_{hXY} = \frac{1}{1000}\left(\frac{\%TRAF_h}{100}\right)\left\{\left(z_{it}\ r_{itw}\right)\left[\sum_q \frac{\%LDV}{100}\ (VMT) \sum_{i=63}^{74} c_{in}\ m_{in}\ v_{is}\right] + \right.$$

$$\left.\left(z'_{it}\ r'_{itwx}\right)\left[\sum_q \frac{\%LDV}{100}\ (VMT) \sum_{i=75} c_{in}\ m_{in}\ v_{is}\right]\right\}$$

Where:

E_{hXY} = LDV emissions in kilograms for hour (h) and grid square (XY)

z_{it} = the temperature correction factor for non-catalyst vehicles (pre-1975 model years) for ambient temperature (t)

r_{itw} = the hot/cold vehicle operation correction factor for non-catalyst LDV at ambient temperature (t) and percentage cold operation (w), defined below

$\%TRAF_h$ = percentage of daily traffic for hour (h) as developed from hourly traffic count data

%LDV = percentage of vehicles that are LDVs for roadway type (q) and grid square (XY), given in Table 16.

VMT = the vehicle miles traveled for roadway type (q) and grid square (XY)

c_{in} = the FTP mean emission factor for the i-th model year LDV during calendar year (n)

m_{in} = the fraction of annual travel by the i-th model year LDV during calendar year (n)

v_{is} = the speed correction factor for the i-th model year LDV and average speed (s)

z'_{it} = the temperature correction factor for catalyst equipped light-duty vehicles (post-1974 model years) and ambient temperature (t)

r'_{itwx} = the hot/cold vehicle operation correction factor for catalyst-equipped LDV ambient temperature (t), percentage cold operation (w) and percentage hot operation (x), defined below

For variables c_{in} and m_{in}, n = 1975.

The hot/cold vehicle operation correction factors r_{itw} and r'_{itwx} are determined by the following equations:

$$r_{itw} = \frac{w + (100-w)f(t)}{20 + 80f(t)} \quad \text{(for pre-1975 model years)}$$

$$r'_{itwx} = \frac{w + xf(t) + (100-w-x)g(t)}{20 + 27f(t) + 53g(t)} \quad \text{(for post-1974 model years)}$$

Where:

$f(t)$, $g(t)$ = functions of ambient temperature (t)

w = the percentage of vehicle operation in the cold start condition, defined to be the first 500 seconds of engine operation after the engine has not been used for a period of at least 5 hours

x = the percentage of hot start operation (vehicle start-up after a short, i.e., less than 1-hour engine-off period). Hot start operation is assumed to occur at the national average of 27 percent.

Cold start weighting was determined using results of the NDH gravity model for traffic flow prediction in the Las Vegas Valley. This model computes the number of trips from one zone to another for different purposes (e.g., work, recrcation, commercial, shopping, etc.). With the percent of starts which are cold starts and the average time per trip for each purpose, the cold starts for each zone are determined on the basis of the following:

$$w_{z(j)} = \sum_{p} \mathrm{COLD}_p \frac{(\mathrm{TRIP}_p)}{\mathrm{TOT\ TRIP}} \left[\frac{8.333}{\mathrm{MIN}_p} \quad \text{or 1 whichever is less} \right]$$

Where:

$w_{z(j)}$ = the percent of vehicle operation in the cold start mode for zone (j)

p = purpose for trip

COLD_p = percent cold starts for a purpose

TRIP_p = number of trips in zone (j) for purpose (p)

TOT TRIP = total number of trips zone (j) square

MIN_p = average number of minutes for a trip of purpose (p)

The zones used in the gravity model overlap the grids used in the emissions inventory. To obtain the percent of cold operation for each grid square, the fractions of zones in each grid square were estimated using a grid overlay on a map of the zones. Based on this overlay, the cold start percentages within a given grid square were calculated using the following formula:

$$w_{XY} = \frac{\sum_{j=1}^{m} (Z_{jXY})\,(TRIP_j)\,(w_{z(j)})}{\sum_{j=1}^{m} (Z_{jXY})\,(TRIP_j)}$$

Where:

w_{XY} = the percent of vehicle operation in the cold start mode in grid square XY

$Z_j XY$ = the percent of the j-th zone contained in grid square X, Y

$TRIP_j$ = total number of trips for zone (j).

This method produced values for cold starts for grid squares ranging from less than 1 percent to 26 percent, with a mean of 14 and a standard deviation of 4.7, compared with the national average of 20 percent. The values were assumed to apply equally during all hours of the day.

Ambient temperature data for use with the LDV equations were obtained from the NWS station at McCarran International Airport assuming spatial homogeneity across the Valley.

Illustrative Example

An illustrative example of total emissions by hour of the day for the various categories described in previous sections is presented in Table B-1. This example is for a constant reference ambient temperature of 10°C.

TABLE B-1. TOTAL CARBON MONOXIDE EMISSIONS (kg/h) FOR LAS VEGAS VALLEY BY SOURCE TYPE FOR CONSTANT REFERENCE TEMPERATURE OF 10° C

	Category (kg/h)	Source Type							
	Hour	1 Power Plant	2 Other Industrial	3 Space Heating	4 Aircraft	5 Railroad	6 LDV	7 HDV	TOTAL
	0	6.2	314.2	13.2	43.0	0.0	2124.8	270.4	2771.8
% of Total		0.22	11.34	0.48	1.55	0.0	76.66	9.76	
	1	6.3	314.2	14.0	97.6	0.0	1593.6	202.8	2228.5
		0.28	14.10	0.63	4.38	0.0	71.51	9.10	
	2	6.5	314.2	13.6	11.6	0.0	1195.2	152.1	1693.2
		0.38	18.56	0.80	0.69	0.0	70.59	8.98	
	3	6.6	314.2	11.6	0.0	119.0	1062.4	135.2	1649.0
		0.40	19.05	0.70	0.0	7.22	64.43	8.20	
	4	6.5	314.2	13.0	0.0	0.0	929.6	118.3	1381.6
		0.47	22.74	0.94	0.0	0.0	67.28	8.56	
	5	6.4	314.2	12.7	2.8	0.0	1328.0	169.0	1833.1
		0.35	17.14	0.69	0.15	0.0	72.45	9.22	
	6	6.8	314.2	13.2	111.1	0.0	3585.6	456.2	4487.1
		0.15	7.00	0.29	2.48	0.0	79.91	10.17	
	7	7.6	314.2	13.6	324.0	0.0	6772.7	861.8	8293.9
		0.09	3.79	0.16	3.91	0.0	81.66	10.39	
	8	8.0	314.2	14.0	548.4	119.0	6905.5	878.7	8787.8
		0.09	3.58	0.16	6.24	1.35	78.58	10.00	
	9	8.3	314.2	14.2	449.1	56.0	6507.1	828.0	8176.9
		0.10	3.84	0.17	5.49	0.68	79.58	10.13	

(continued)

TABLE B-1. TOTAL CARBON MONOXIDE EMISSIONS (kg/h) FOR LAS VEGAS VALLEY BY SOURCE TYPE FOR CONSTANT REFERENCE TEMPERATURE OF 10°C (continued)

Category (kg/h) Hour		Source Type 1 Power Plant	2 Other Industrial	3 Space Heating	4 Aircraft	5 Railroad	6 LDV	7 HDV	TOTAL
10		9.2	314.2	14.1	510.6	56.0	7171.1	912.5	8987.7
	% of Total	0.10	3.50	0.16	5.68	0.62	79.79	10.15	
11		9.3	314.2	13.3	458.6	0.0	7967.9	1013.9	9777.2
		0.10	3.21	0.14	4.69	0.0	81.49	10.37	
12		9.0	314.2	13.1	463.4	0.0	8764.7	1115.3	10679.7
		0.08	2.94	0.12	4.34	0.0	82.07	10.44	
13		8.6	314.2	11.9	556.1	0.0	8499.1	1081.5	10471.4
		0.08	3.00	0.11	5.31	0.0	81.16	10.33	
14		8.1	314.2	11.2	429.7	56.0	8764.7	1115.3	10699.2
		0.08	2.94	0.10	4.02	0.52	81.92	10.42	
15		7.5	314.2	10.2	350.0	119.0	9827.1	1250.5	11878.5
		0.06	2.65	0.09	2.95	1.00	82.73	10.53	
16		7.1	314.2	10.2	281.3	0.0	10623.9	1351.8	12588.5
		0.06	2.50	0.08	2.23	0.0	84.39	10.74	
17		7.1	314.2	10.7	440.2	0.0	9959.9	1267.4	11999.5
		0.06	2.62	0.09	3.67	0.0	83.00	10.56	
18		6.8	314.2	10.5	287.2	0.0	7171.1	912.5	8702.3
		0.08	3.61	0.12	3.30	0.0	82.40	10.49	
19		6.6	314.2	10.3	322.3	0.0	6241.5	794.2	7689.1
		0.09	4.09	0.13	4.19	0.0	81.17	10.33	

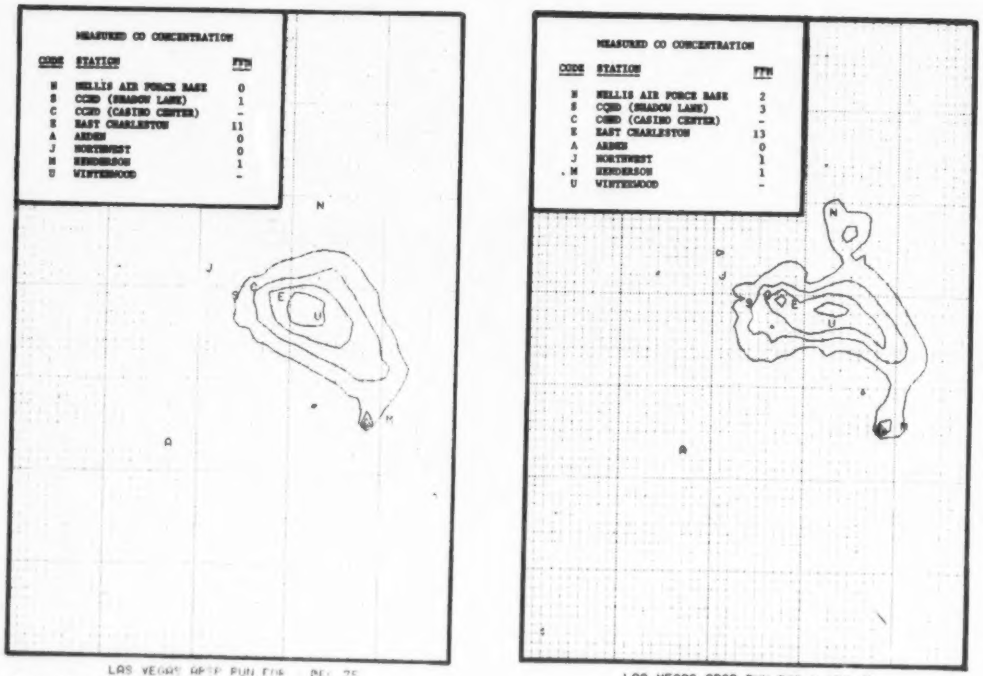
(continued)

TABLE B-1. TOTAL CARBON MONOXIDE EMISSIONS (kg/h) FOR LAS VEGAS VALLEY BY SOURCE TYPE FOR CONSTANT REFERENCE TEMPERATURE OF 10°C (continued)

Category (kg/h)		Source Type							
	Hour	1 Power Plant	2 Other Industrial	3 Space Heating	4 Aircraft	5 Railroad	6 LDV	7 HDV	TOTAL
	20	5.8	314.2	11.6	215.8	0.0	5046.4	642.1	6235.9
% of Total		0.09	5.04	0.19	3.46	0.0	80.92	10.30	
	21	5.7	314.2	12.4	111.3	119.0	4249.6	540.7	5352.9
		0.11	5.87	0.23	2.08	2.22	79.39	10.10	
	22	5.8	314.2	12.4	116.8	56.0	3452.8	439.4	4397.4
		0.13	7.15	0.28	2.66	1.27	78.52	9.99	
	23	5.5	314.2	12.4	254.0	56.0	3054.4	388.7	4085.2
		0.13	7.69	0.30	6.22	1.37	74.77	9.51	
TOTAL (kg/day)		171.3	7540.8	297.4	6384.9	756.0	132798.7	16898.3	164847.4
% of TOTAL		0.10	4.57	0.18	3.87	0.46	80.56	10.25	

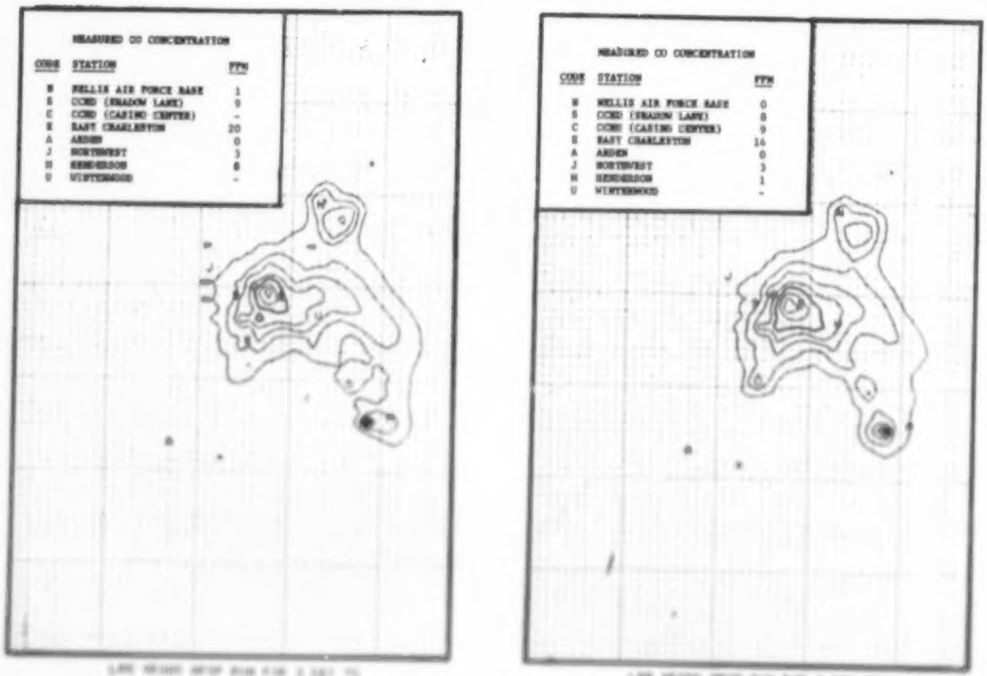
NOTE: Hour 0 is from 0000 to 0059 Local Standard Time.

APPENDIX C
ISOPLETH MAPS OF SIMULATION DAYS
(Contours in Units of 2 ppm CO)


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) -
E EAST CHARLESTON 11
A ARDEN 0
J NORTHWEST 0
M HENDERSON 1
U WINTERWOOD -
N
J
C
S
E
U
A
M
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 2
S CCHD (SHADOW LANE) 3
C CCHD (CASINO CENTER) -
E EAST CHARLESTON 13
A ARDEN 0
J NORTHWEST 1
M HENDERSON 1
U WINTERWOOD -
N
J
E
U
A

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 500 AND 600 PST

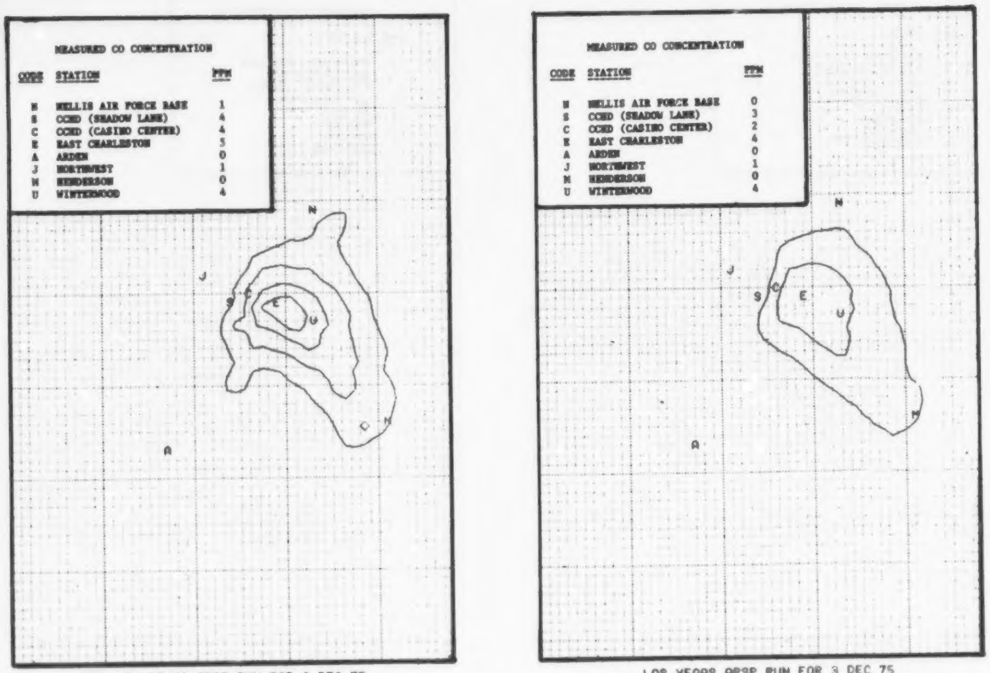
LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 600 AND 700 PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 1
S CCHD (SHADOW LANE) 9
C CCHD (CASINO CENTER) -
E EAST CHARLESTON 20
A ARDEN 0
J NORTHWEST 3
M HENDERSON 8
U WINTERWOOD -
N
J
U
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 8
C CCHD (CASINO CENTER) 9
E EAST CHARLESTON 16
A ARDEN 0
J NORTHWEST 3
M HENDERSON 1
U WINTERWOOD -
N
J

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 700 AND 800 PST

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 800 AND 900 PST

Figure C-1.



MEASURED CO CONCENTRATION

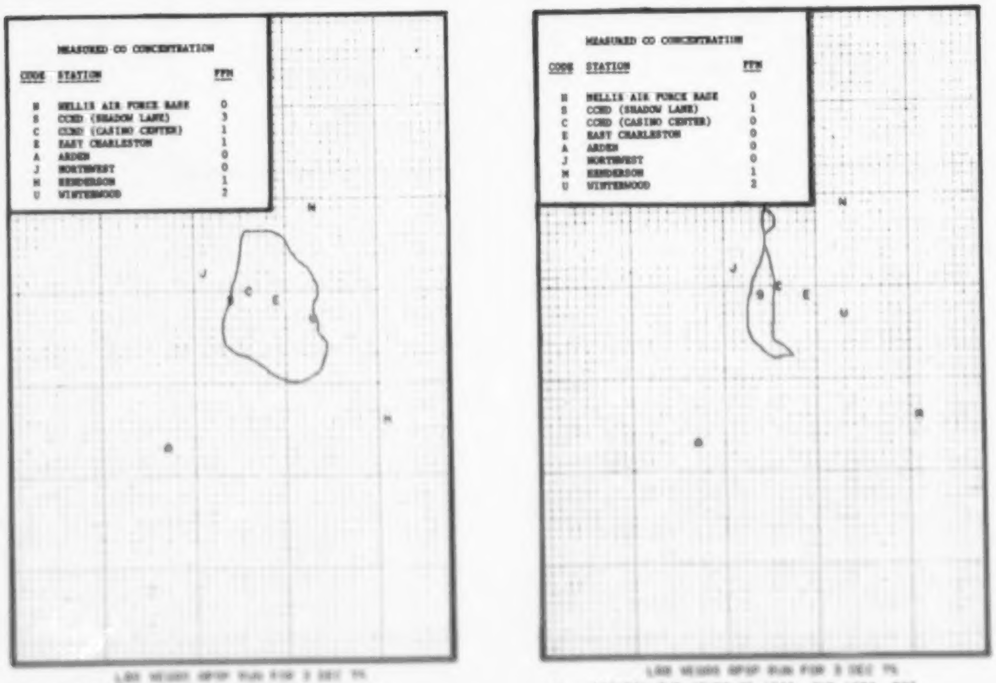
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	1
S	CCHD (SHADOW LANE)	4
C	CCHD (CASINO CENTER)	4
E	EAST CHARLESTON	5
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	0
U	WINTERWOOD	4

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 900. AND 1000. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	2
E	EAST CHARLESTON	4
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	0
U	WINTERWOOD	4

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1000. AND 1100. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	1
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	0
H	HENDERSON	1
U	WINTERWOOD	2

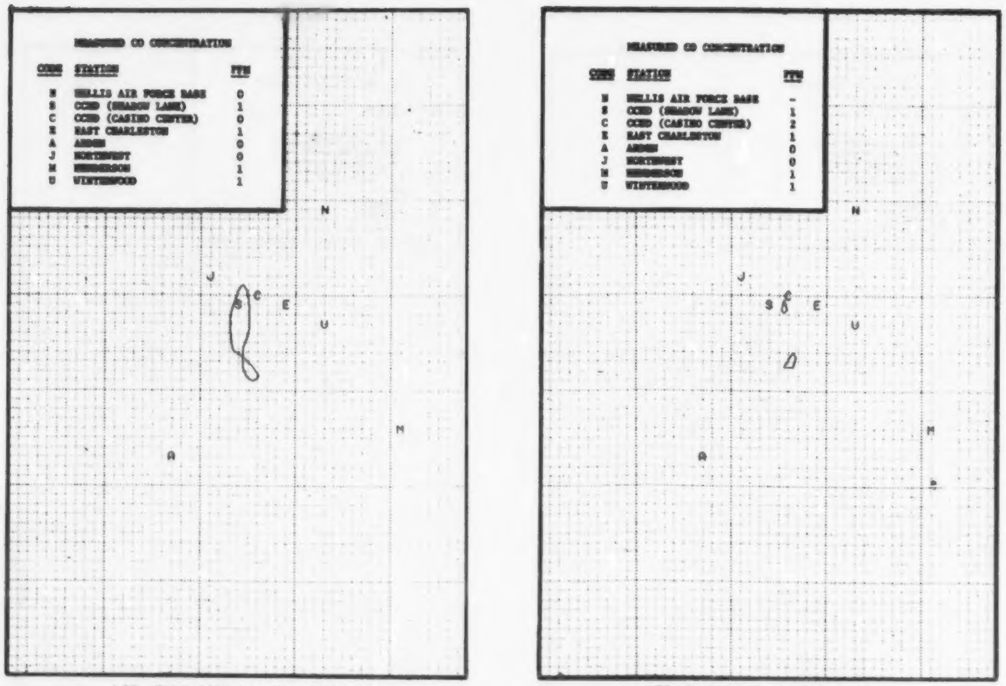
LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1100. AND 1200. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	0
E	EAST CHARLESTON	0
A	ARDEN	0
J	NORTHWEST	0
H	HENDERSON	1
U	WINTERWOOD	2

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1200. AND 1300. PST

Figure C-2.



MEASURED CO CONCENTRATION

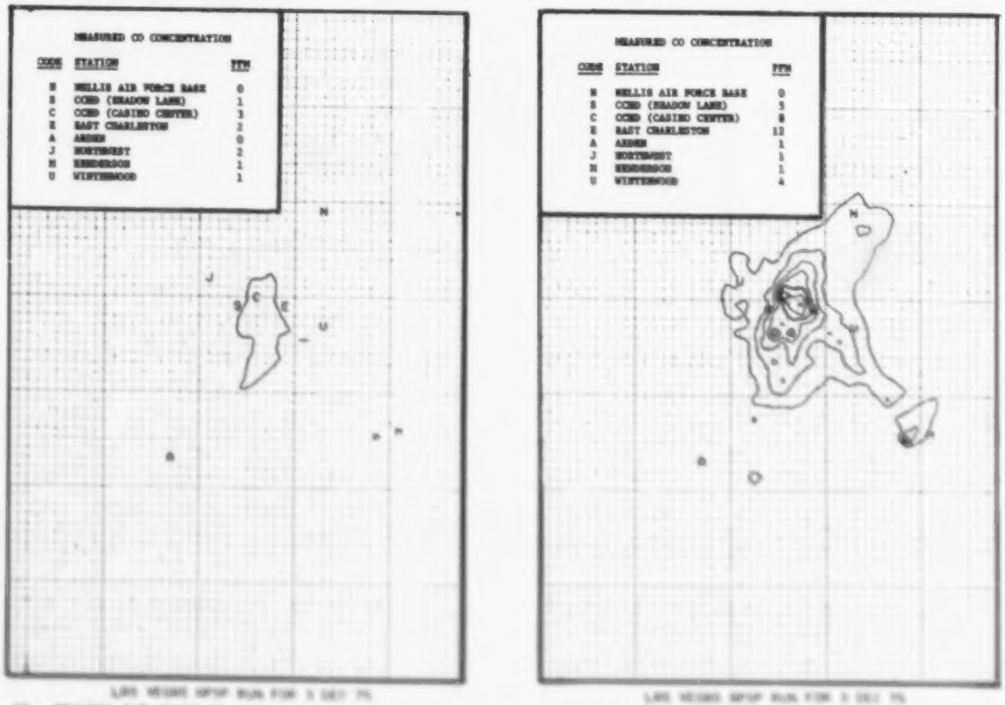
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	0
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	0
M	HENDERSON	1
U	WINTERWOOD	1

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1300. AND 1400. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	2
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	0
M	HENDERSON	1
U	WINTERWOOD	1

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1400. AND 1500. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	3
E	EAST CHARLESTON	2
A	ARDEN	0
J	NORTHWEST	2
M	HENDERSON	1
U	WINTERWOOD	1

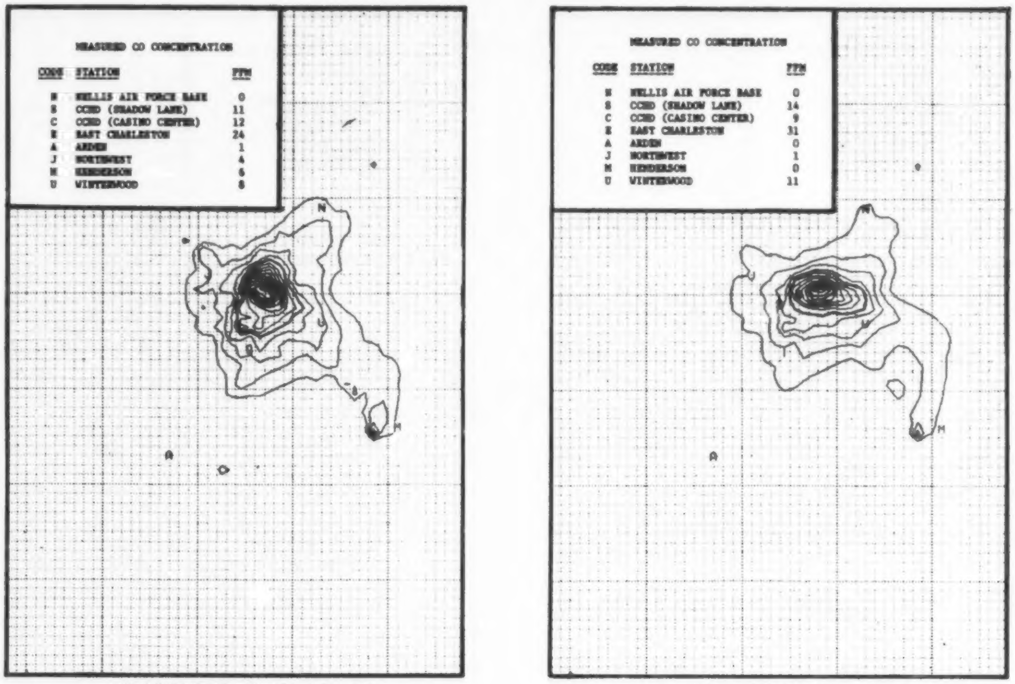
LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1500. AND 1600. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	5
C	CCHD (CASINO CENTER)	8
E	EAST CHARLESTON	12
A	ARDEN	1
J	NORTHWEST	1
M	HENDERSON	1
U	WINTERWOOD	4

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1600. AND 1700. PST

Figure C-3.



MEASURED CO CONCENTRATION

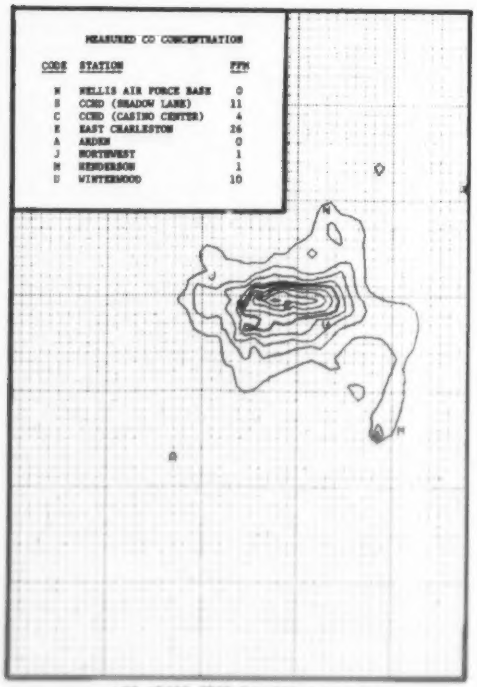
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	11
C	CCHD (CASINO CENTER)	12
E	EAST CHARLESTON	24
A	ARDEN	1
J	NORTHWEST	4
M	HENDERSON	6
U	WINTERWOOD	8

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1700. AND 1800. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	14
C	CCHD (CASINO CENTER)	9
E	EAST CHARLESTON	31
A	ARDEN	0
J	NORTHWEST	1
M	HENDERSON	0
U	WINTERWOOD	11

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1800. AND 1900. PST

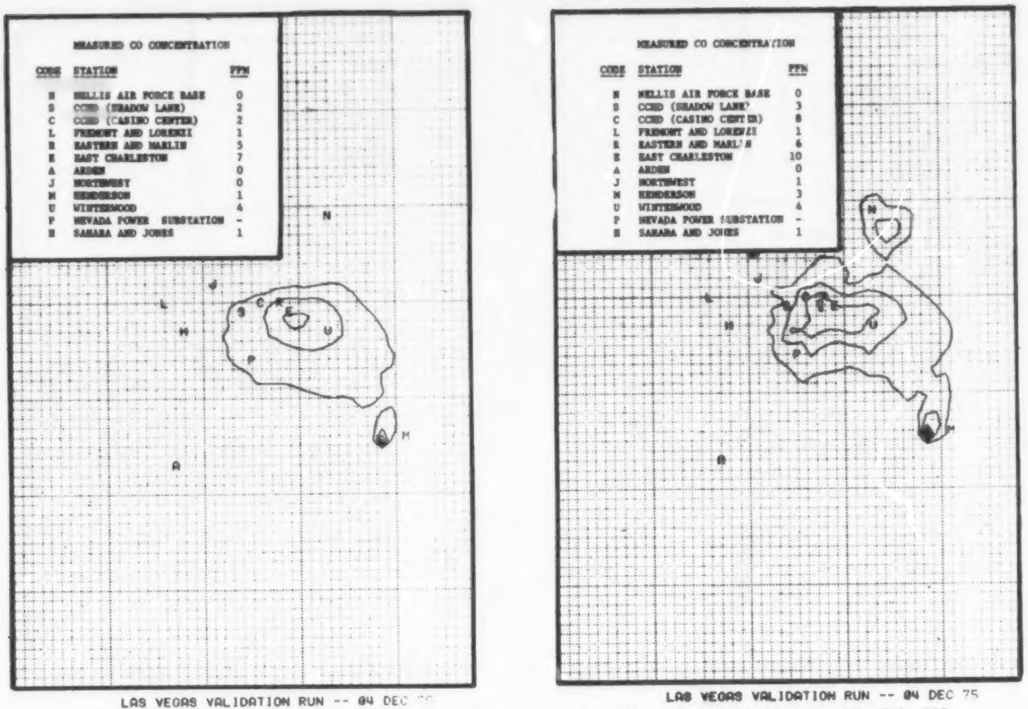


MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	11
C	CCHD (CASINO CENTER)	4
E	EAST CHARLESTON	26
A	ARDEN	0
J	NORTHWEST	1
M	HENDERSON	1
U	WINTERWOOD	10

LAS VEGAS APSP RUN FOR 3 DEC 75
CO BETWEEN THE HOURS OF 1900. AND 2000. PST

Figure C-4.



MEASURED CO CONCENTRATION

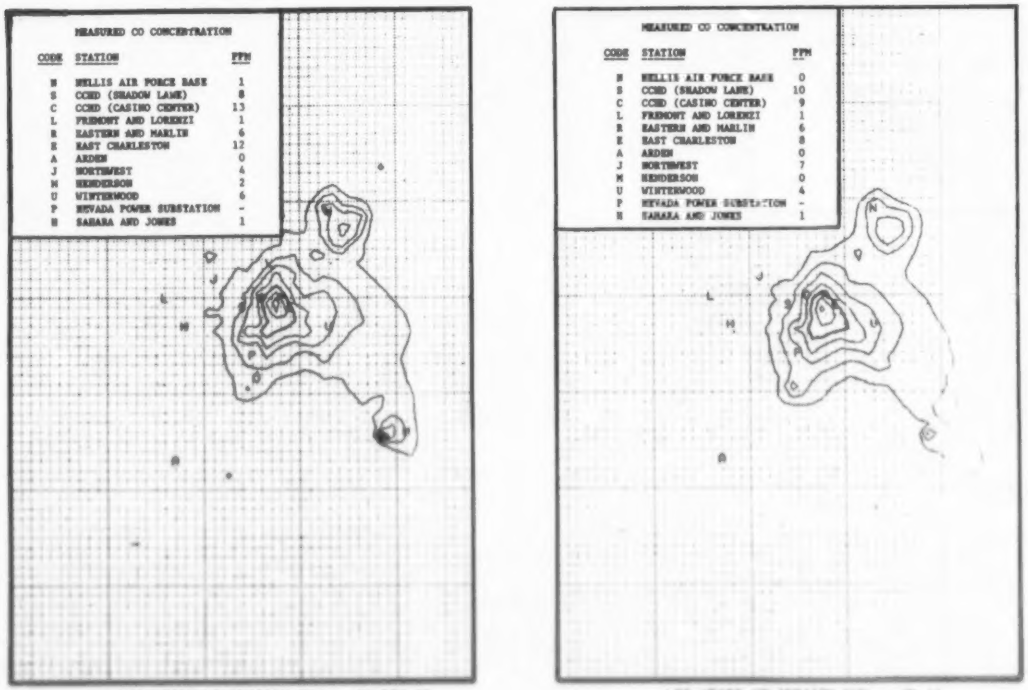
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	2
C	CCHD (CASINO CENTER)	2
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	5
E	EAST CHARLESTON	7
A	ARDEN	0
J	NORTHWEST	0
M	HENDERSON	1
U	WINTERWOOD	4
P	NEVADA POWER SUBSTATION	-
H	SAHARA AND JONES	1

LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 500. AND 600. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	8
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	6
E	EAST CHARLESTON	10
A	ARDEN	0
J	NORTHWEST	1
M	HENDERSON	3
U	WINTERWOOD	4
P	NEVADA POWER SUBSTATION	-
H	SAHARA AND JONES	1

LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 600. AND 700. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	1
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	13
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	6
E	EAST CHARLESTON	12
A	ARDEN	0
J	NORTHWEST	4
M	HENDERSON	2
U	WINTERWOOD	6
P	NEVADA POWER SUBSTATION	-
H	SAHARA AND JONES	1

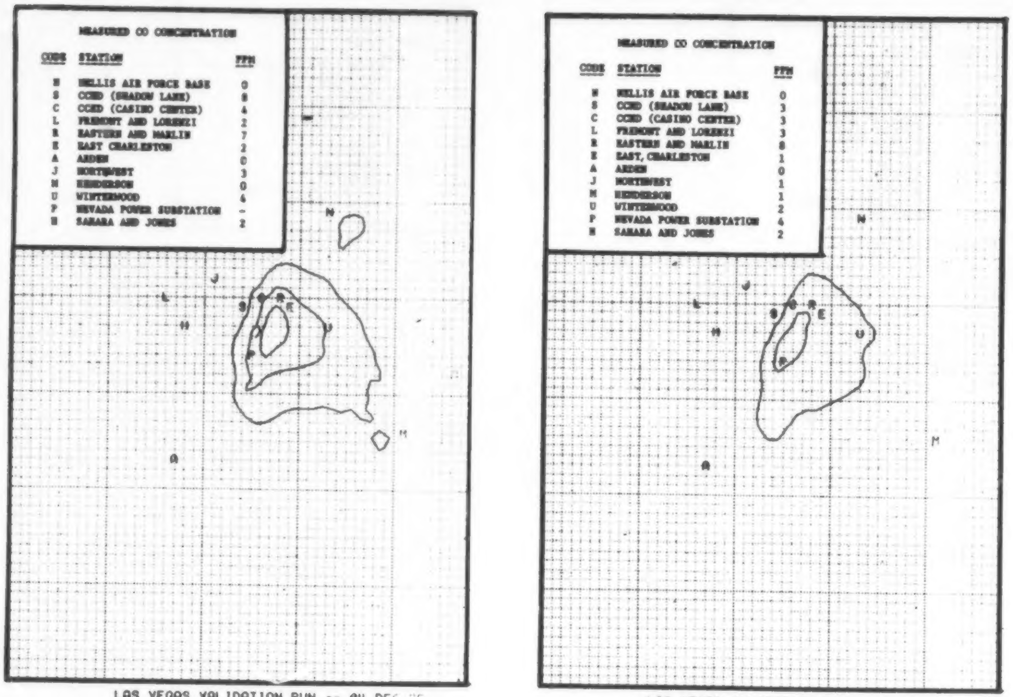
LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 700. AND 800. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	10
C	CCHD (CASINO CENTER)	9
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	6
E	EAST CHARLESTON	8
A	ARDEN	0
J	NORTHWEST	7
M	HENDERSON	0
U	WINTERWOOD	4
P	NEVADA POWER SUBSTATION	-
H	SAHARA AND JONES	1

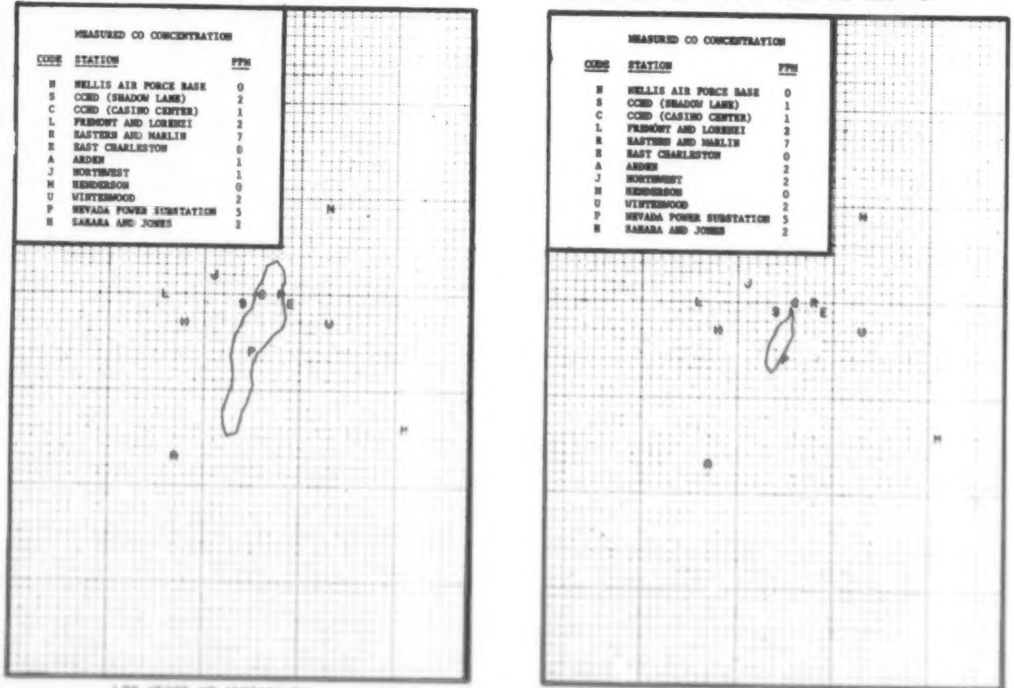
LAS VEGAS VALIDATION RUN -- 04 [illegible]
CO BETWEEN THE HOURS OF 800. AND [illegible]

Figure C-5.


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 8
C CCHD (CASINO CENTER) 4
L FREMONT AND LORENZI 2
R EASTERN AND MARLIN 7
E EAST CHARLESTON 2
A ARDEN 0
J NORTHWEST 3
H HENDERSON 0
U WINTERWOOD 4
P NEVADA POWER SUBSTATION -
H SAHARA AND JONES 2
N
J
L
S
C
R
E
H
U
P
M
A
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 3
C CCHD (CASINO CENTER) 3
L FREMONT AND LORENZI 3
R EASTERN AND MARLIN 8
E EAST, CHARLESTON 1
A ARDEN 0
J NORTHWEST 1
H HENDERSON 1
U WINTERWOOD 2
P NEVADA POWER SUBSTATION 4
H SAHARA AND JONES 2
N
J
L
S
C
R
E
H
U
P
M
A

LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 900. AND 1000. PST

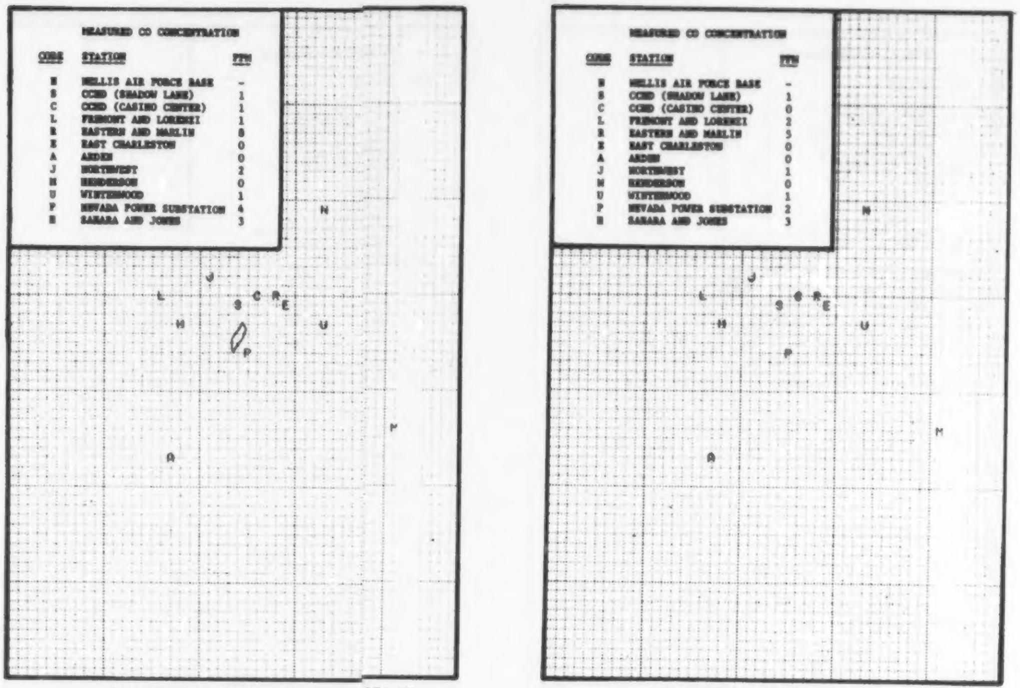
LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 1000. AND 1100. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 2
C CCHD (CASINO CENTER) 1
L FREMONT AND LORENZI 2
R EASTERN AND MARLIN 7
E EAST CHARLESTON 0
A ARDEN 1
J NORTHWEST 1
H HENDERSON 0
U WINTERWOOD 2
P NEVADA POWER SUBSTATION 5
H SAHARA AND JONES 2
N
J
L
S
C
R
E
H
U
P
M
A
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 1
L FREMONT AND LORENZI 2
R EASTERN AND MARLIN 7
E EAST CHARLESTON 0
A ARDEN 2
J NORTHWEST 2
H HENDERSON 0
U WINTERWOOD 2
P NEVADA POWER SUBSTATION 5
H SAHARA AND JONES 2
N
J
L
S
C
R
E
H
U
P
M
A

LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 1100. AND 1200. PST

LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 1200. AND 1300. PST

Figure C-6.



MEASURED CO CONCENTRATION

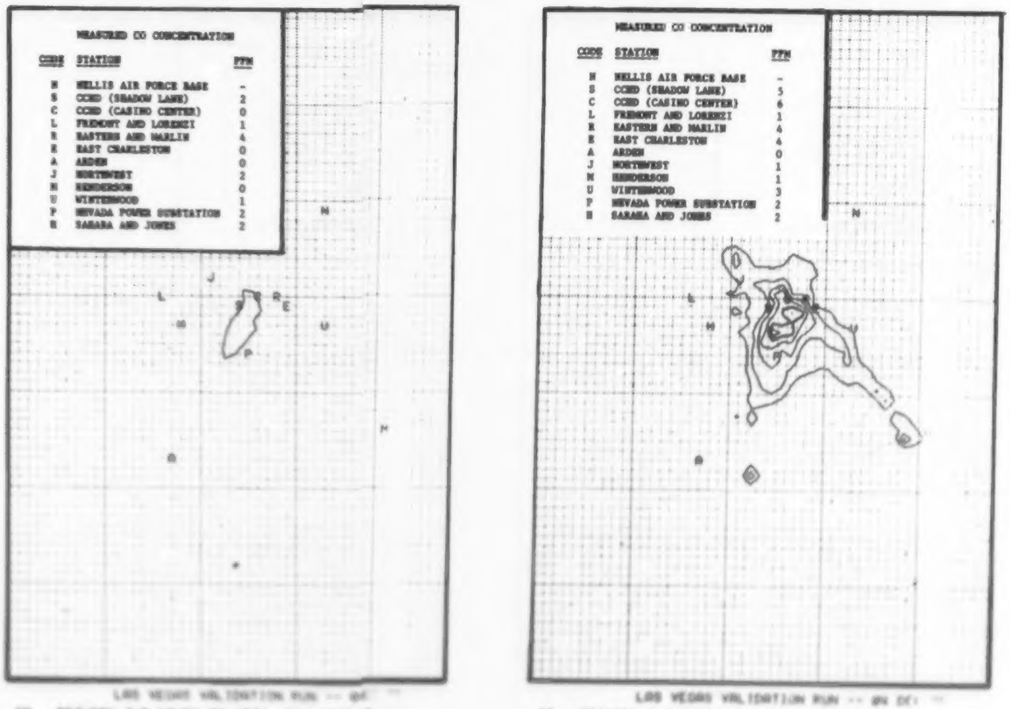
CODE	STATION	PPM
W	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	1
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	8
E	EAST CHARLESTON	0
A	ARDEN	0
J	NORTHWEST	2
H	HENDERSON	0
U	WINTERWOOD	1
P	NEVADA POWER SUBSTATION	4
B	SAHARA AND JONES	3

LAS VEGAS VALIDATION RUN -- 04DEC
CO BETWEEN THE HOURS OF 1300. AND 1400. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
W	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	0
L	FREMONT AND LORENZI	2
R	EASTERN AND MARLIN	5
E	EAST CHARLESTON	0
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	0
U	WINTERWOOD	1
P	NEVADA POWER SUBSTATION	2
B	SAHARA AND JONES	3

LAS VEGAS VALIDATION RUN -- 04 DEC
CO BETWEEN THE HOURS OF 1400. AND 1500. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
W	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	2
C	CCHD (CASINO CENTER)	0
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	4
E	EAST CHARLESTON	0
A	ARDEN	0
J	NORTHWEST	2
H	HENDERSON	0
U	WINTERWOOD	1
P	NEVADA POWER SUBSTATION	2
B	SAHARA AND JONES	2

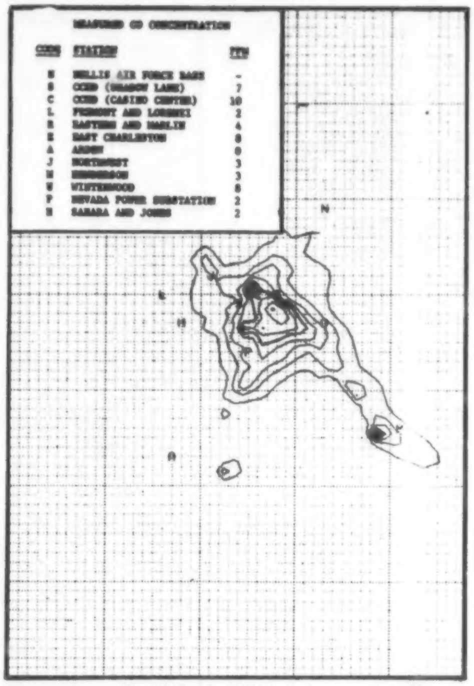
LAS VEGAS VALIDATION RUN -- 04
CO BETWEEN THE HOURS OF 1500. AND 1600.

MEASURED CO CONCENTRATION

CODE	STATION	PPM
W	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	5
C	CCHD (CASINO CENTER)	6
L	FREMONT AND LORENZI	1
R	EASTERN AND MARLIN	4
E	EAST CHARLESTON	4
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	1
U	WINTERWOOD	3
P	NEVADA POWER SUBSTATION	2
B	SAHARA AND JONES	2

LAS VEGAS VALIDATION RUN -- 04 DEC
CO BETWEEN THE HOURS OF 1600. AND 1700. PST

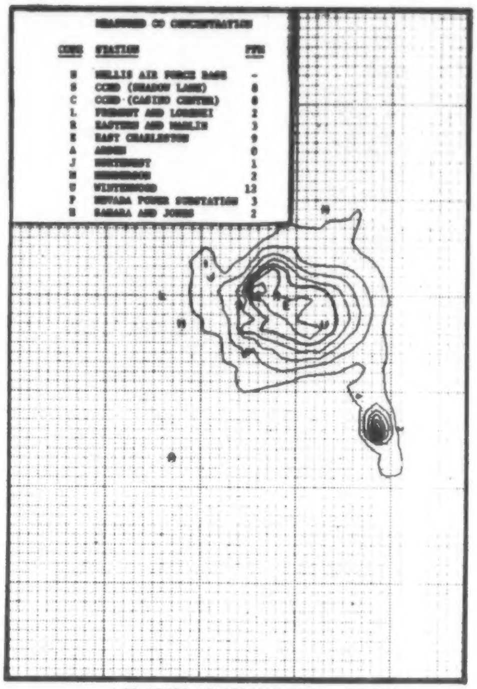
Figure C-7.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	7
C	CCHD (CASINO CENTER)	10
L	FREMONT AND LORENZI	2
R	EASTERN AND MARLIN	4
E	EAST CHARLESTON	8
A	ARDEN	0
J	NORTHWEST	3
H	HENDERSON	3
U	WINTERWOOD	8
P	NEVADA POWER SUBSTATION	2
B	SAHARA AND JONES	2

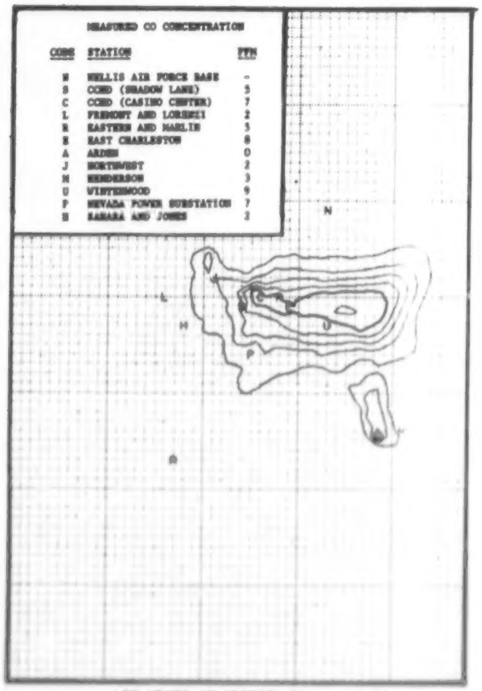
LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 1700. AND 1800. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	8
L	FREMONT AND LORENZI	2
R	EASTERN AND MARLIN	3
E	EAST CHARLESTON	9
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	2
U	WINTERWOOD	12
P	NEVADA POWER SUBSTATION	3
B	SAHARA AND JONES	2

LAS VEGAS VALIDATION RUN -- 04 DEC 75
CO BETWEEN THE HOURS OF 1800. AND 1900. PST

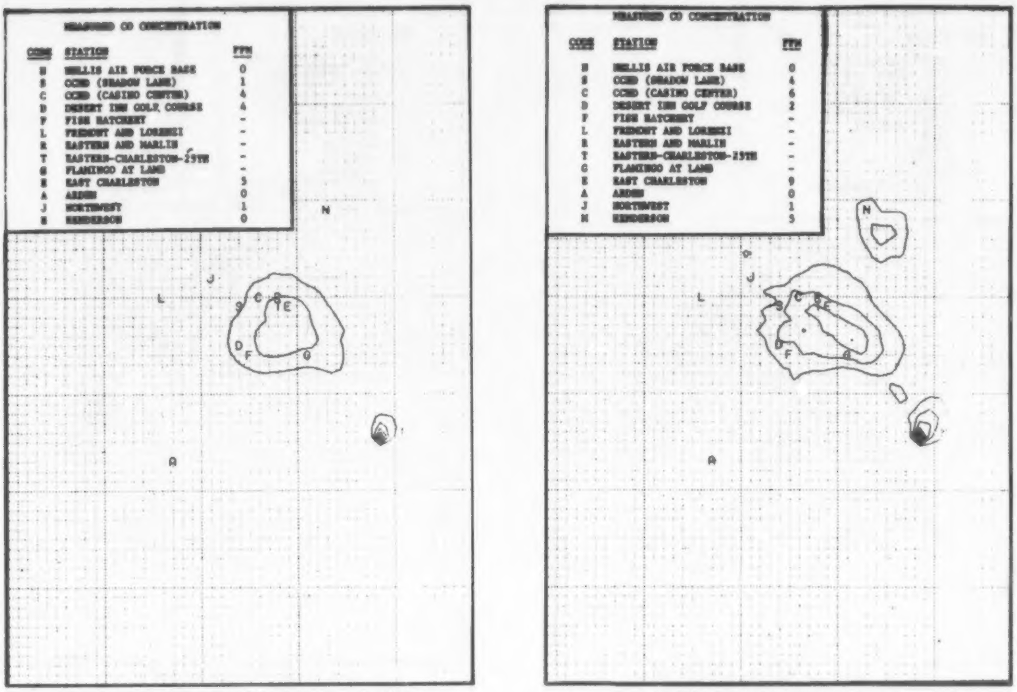


MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	5
C	CCHD (CASINO CENTER)	7
L	FREMONT AND LORENZI	2
R	EASTERN AND MARLIN	5
E	EAST CHARLESTON	8
A	ARDEN	0
J	NORTHWEST	2
H	HENDERSON	3
U	WINTERWOOD	9
P	NEVADA POWER SUBSTATION	7
B	SAHARA AND JONES	2

LAS VEGAS VALIDATION RUN -- 04 DEC
CO BETWEEN THE HOURS OF 1900. AND 2000. PST

Figure C-8.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	4
D	DESERT INN GOLF COURSE	4
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	-
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAND	-
E	EAST CHARLESTON	5
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	0

LAS VEGAS VALIDATION RUN -- 14 JAN

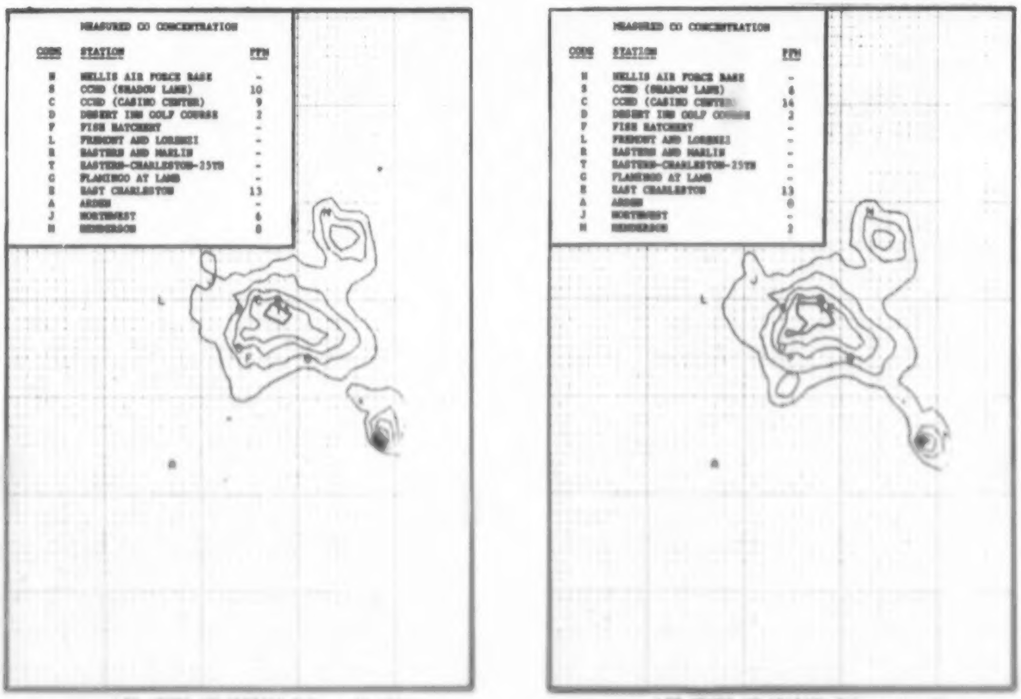
CO BETWEEN THE HOURS OF 500. AND 600. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	4
C	CCHD (CASINO CENTER)	6
D	DESERT INN GOLF COURSE	2
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	-
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAND	-
E	EAST CHARLESTON	9
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	5

LAS VEGAS VALIDATION RUN -- 14 JAN

CO BETWEEN THE HOURS OF 600. AND 700. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	10
C	CCHD (CASINO CENTER)	9
D	DESERT INN GOLF COURSE	2
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	-
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAND	-
E	EAST CHARLESTON	13
A	ARDEN	-
J	NORTHWEST	6
H	HENDERSON	8

LAS VEGAS VALIDATION RUN -- 14 JAN

CO BETWEEN THE HOURS OF [illegible] AND [illegible] PST

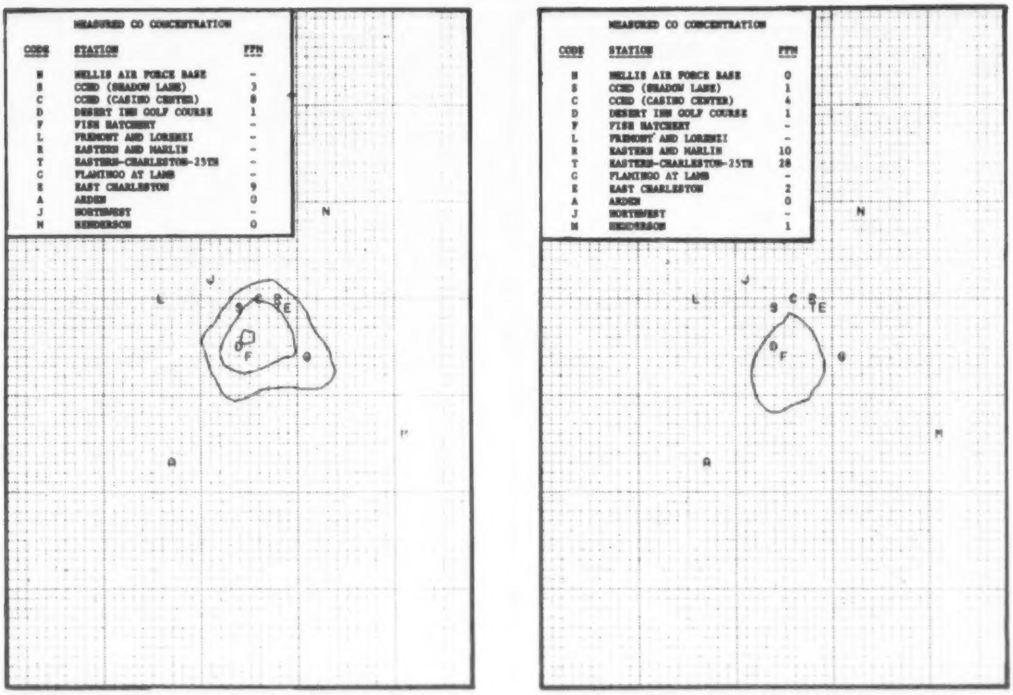
MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	14
D	DESERT INN GOLF COURSE	2
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	-
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAND	-
E	EAST CHARLESTON	13
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	2

LAS VEGAS VALIDATION RUN -- 14 JAN

CO BETWEEN THE HOURS OF [illegible] AND [illegible] PST

Figure C-9.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	-
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	8
D	DESERT INN GOLF COURSE	1
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	-
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	-
E	EAST CHARLESTON	9
A	ARDEN	0
J	NORTHWEST	-
M	HENDERSON	0

LAS VEGAS VALIDATION RUN -- 14 JAN 7

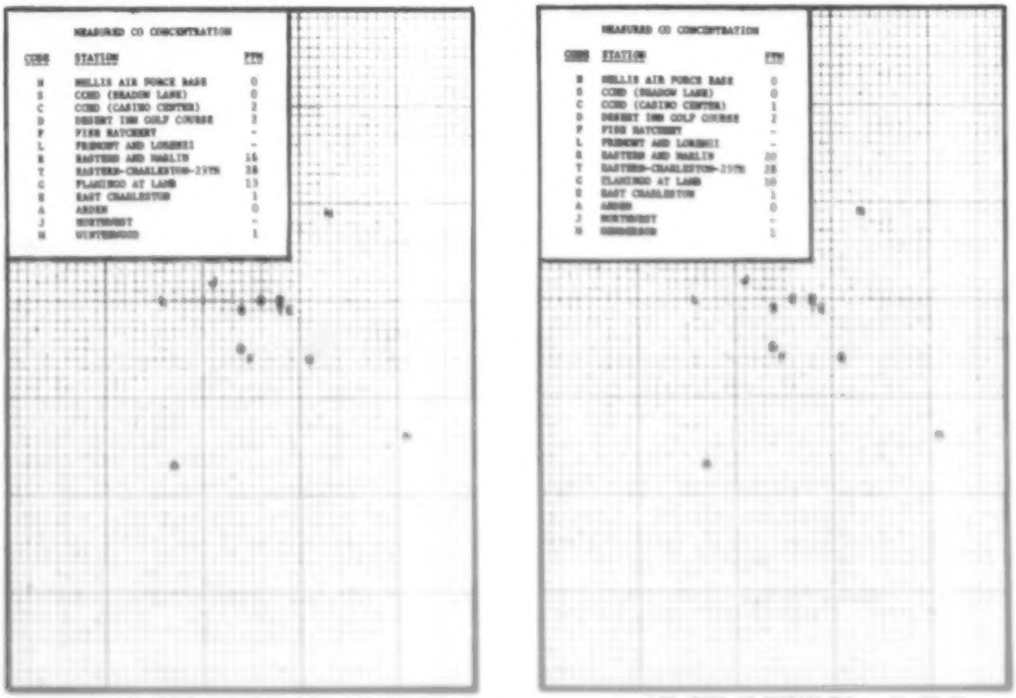
CO BETWEEN THE HOURS OF 900. AND 1000. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	4
D	DESERT INN GOLF COURSE	1
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	10
T	EASTERN-CHARLESTON-25TH	28
G	FLAMINGO AT LAMB	-
E	EAST CHARLESTON	2
A	ARDEN	0
J	NORTHWEST	-
M	HENDERSON	1

LAS VEGAS VALIDATION RUN -- 14 JAN 7

CO BETWEEN THE HOURS OF 1000. AND 1100. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	0
C	CCHD (CASINO CENTER)	2
D	DESERT INN GOLF COURSE	2
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	16
T	EASTERN-CHARLESTON-25TH	28
G	FLAMINGO AT LAMB	13
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
M	WINTERWOOD	1

LAS VEGAS VALIDATION RUN -- 14 JAN 7

CO BETWEEN THE HOURS OF 1100. AND 1200. PST

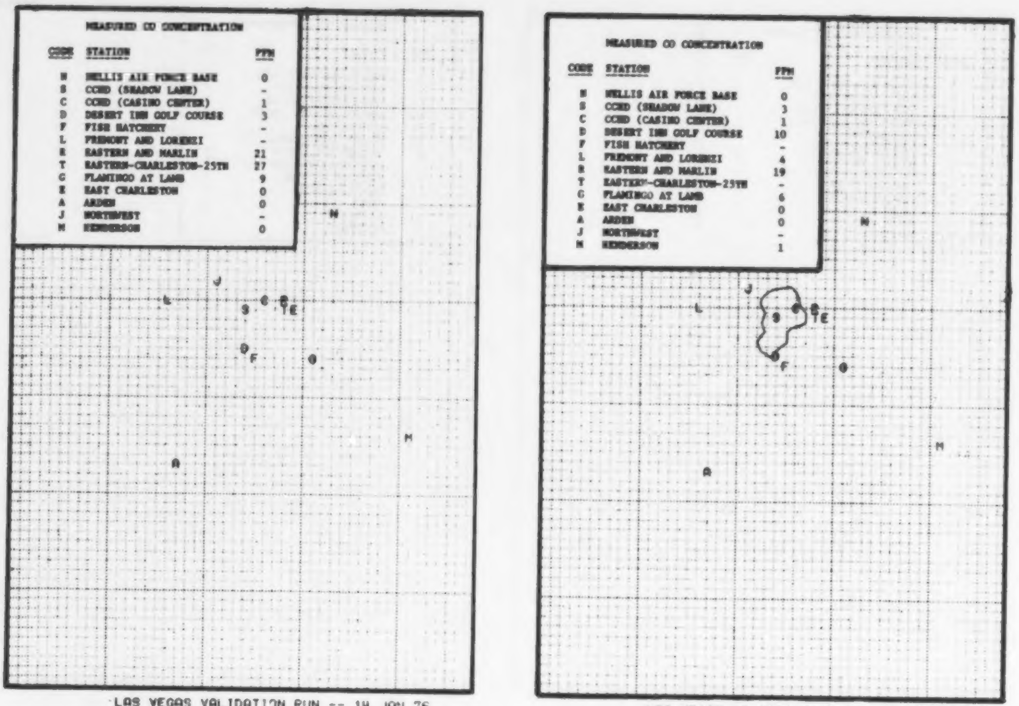
MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	0
C	CCHD (CASINO CENTER)	1
D	DESERT INN GOLF COURSE	2
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	20
T	EASTERN-CHARLESTON-25TH	28
G	FLAMINGO AT LAMB	10
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
M	HENDERSON	1

LAS VEGAS VALIDATION RUN -- 14 JAN 7

CO BETWEEN THE HOURS OF 1200. AND 1300. PST

Figure C-10.



MEASURED CO CONCENTRATION

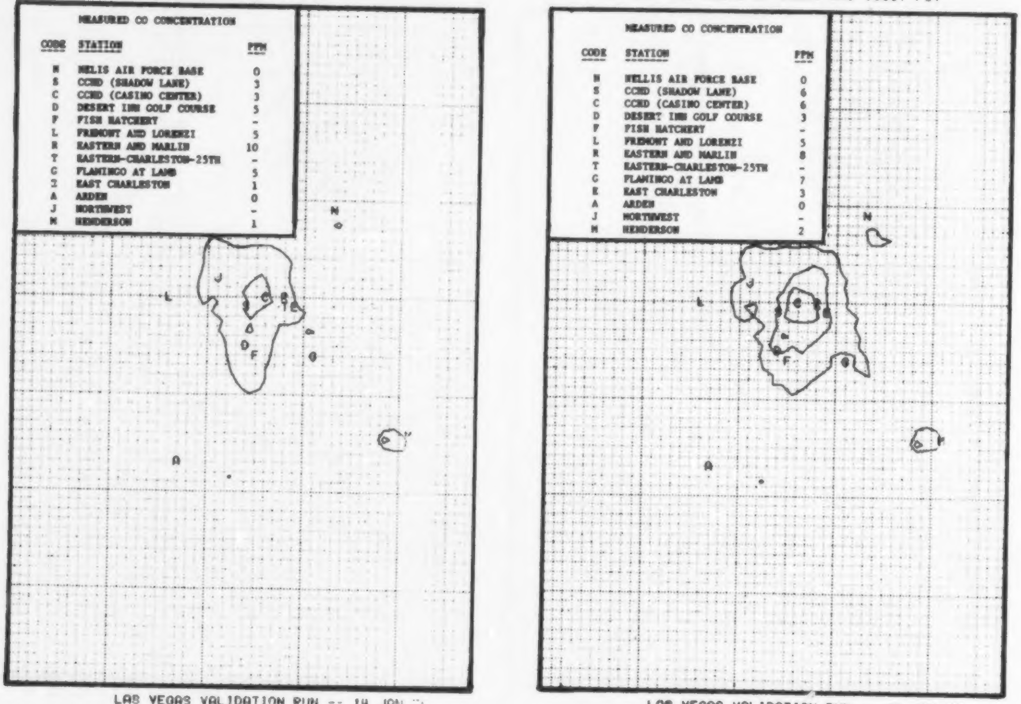
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	-
C	CCHD (CASINO CENTER)	1
D	DESERT INN GOLF COURSE	3
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	-
R	EASTERN AND MARLIN	21
T	EASTERN-CHARLESTON-25TH	27
G	FLAMINGO AT LAMB	9
E	EAST CHARLESTON	0
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	0

LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1300. AND 1400. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	1
D	DESERT INN GOLF COURSE	10
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	4
R	EASTERN AND MARLIN	19
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	6
E	EAST CHARLESTON	0
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	1

LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1400. AND 1500. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	3
D	DESERT INN GOLF COURSE	5
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	5
R	EASTERN AND MARLIN	10
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	5
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	1

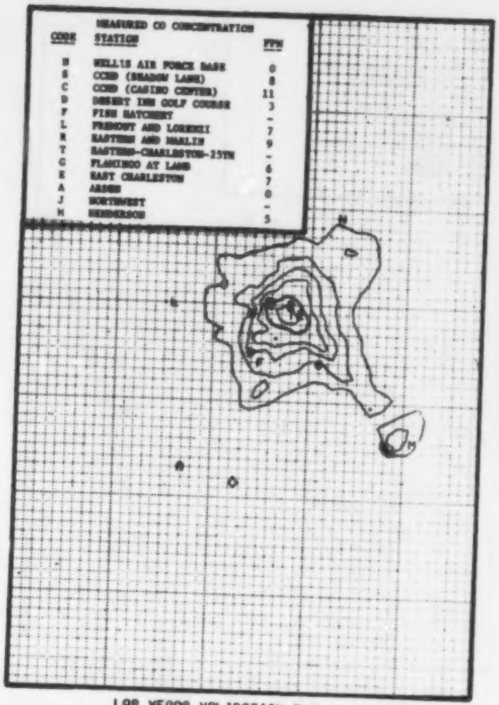
LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1500. AND 1600. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	6
C	CCHD (CASINO CENTER)	6
D	DESERT INN GOLF COURSE	3
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	5
R	EASTERN AND MARLIN	8
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	7
E	EAST CHARLESTON	3
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	2

LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1600. AND 1700. PST

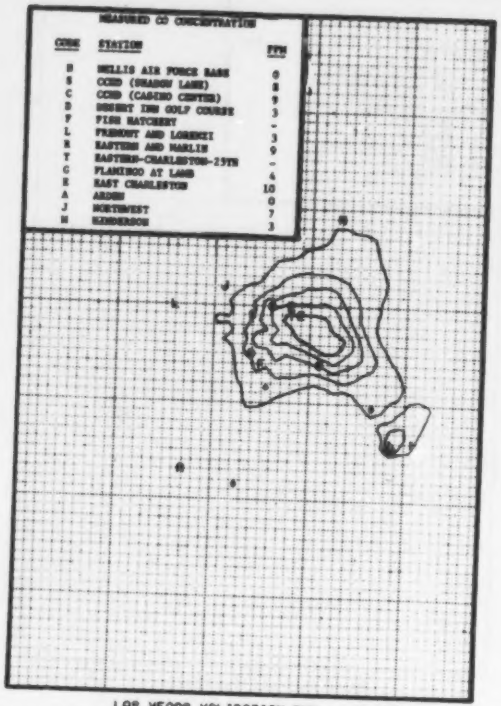
Figure C-11.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	11
D	DESERT INN GOLF COURSE	3
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	7
R	EASTERN AND MARLIN	9
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	6
E	EAST CHARLESTON	7
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	5

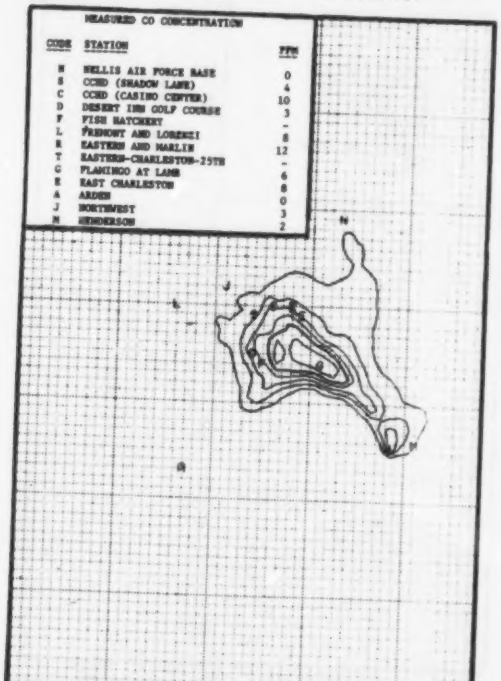
LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1700. AND 1800. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	9
D	DESERT INN GOLF COURSE	3
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	3
R	EASTERN AND MARLIN	9
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	4
E	EAST CHARLESTON	10
A	ARDEN	0
J	NORTHWEST	7
H	HENDERSON	3

LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1800. AND 1900. PST

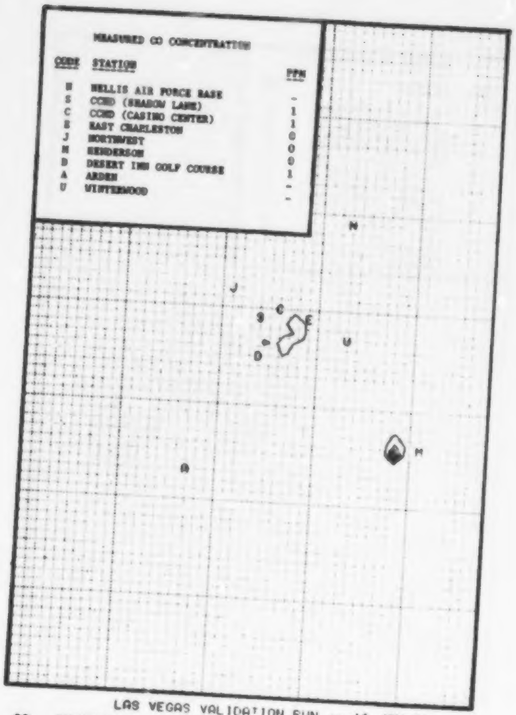


MEASURED CO CONCENTRATION

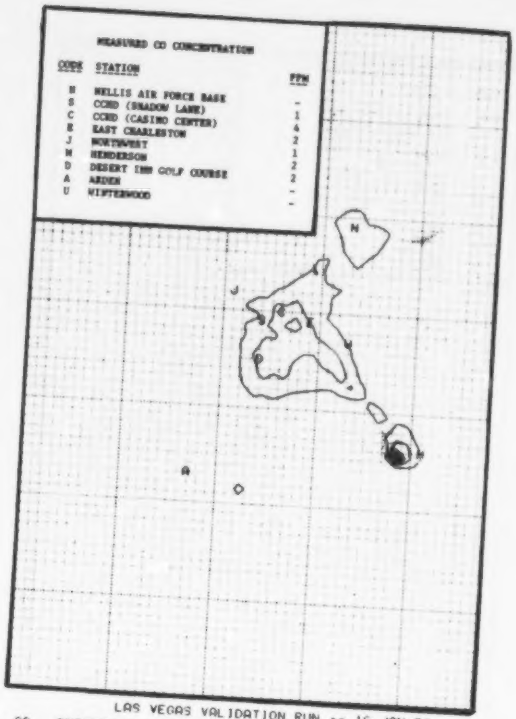
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	4
C	CCHD (CASINO CENTER)	10
D	DESERT INN GOLF COURSE	3
F	FISH HATCHERY	-
L	FREMONT AND LORENZI	8
R	EASTERN AND MARLIN	12
T	EASTERN-CHARLESTON-25TH	-
G	FLAMINGO AT LAMB	6
E	EAST CHARLESTON	8
A	ARDEN	0
J	NORTHWEST	3
H	HENDERSON	2

LAS VEGAS VALIDATION RUN -- 14 JAN 76
CO BETWEEN THE HOURS OF 1900. AND 2000. PST

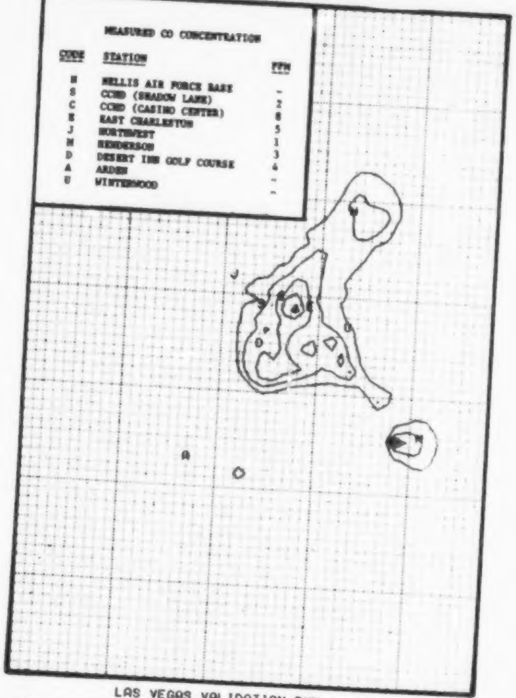
Figure C-12.


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 1
E EAST CHARLESTON 0
J NORTHWEST 0
M HENDERSON 0
D DESERT INN GOLF COURSE 1
A ARDEN -
U WINTERWOOD -
N
J
C
S
E
U
D
M
A

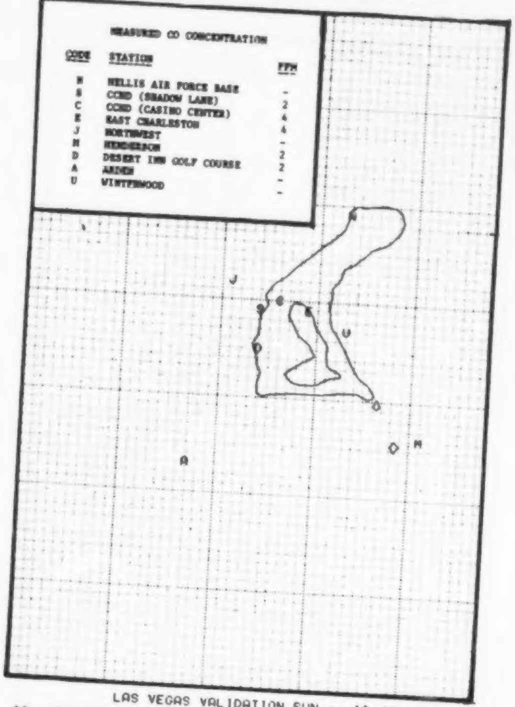
LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 500. AND 600. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 4
E EAST CHARLESTON 2
J NORTHWEST 1
M HENDERSON 2
D DESERT INN GOLF COURSE 2
A ARDEN -
U WINTERWOOD -
N
J
E
U
D
M
A

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 600. AND 700. PST

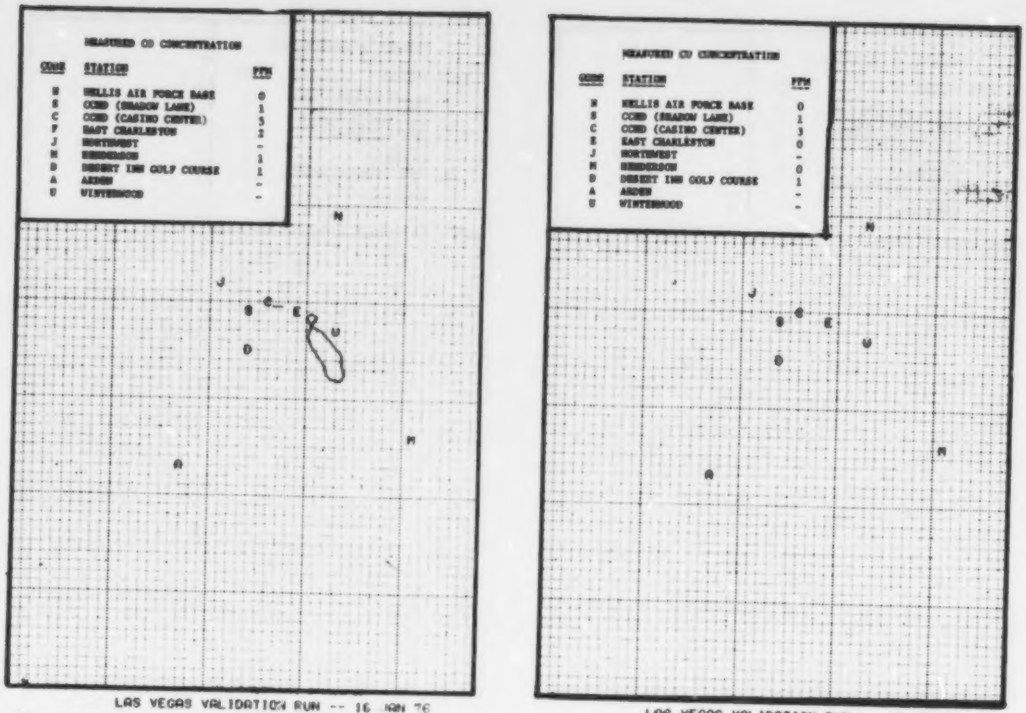

MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 2
C CCHD (CASINO CENTER) 8
E EAST CHARLESTON 5
J NORTHWEST 1
M HENDERSON 3
D DESERT INN GOLF COURSE 4
A ARDEN -
U WINTERWOOD -
N
J
U
M
A

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 700. AND 800. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 2
C CCHD (CASINO CENTER) 4
E EAST CHARLESTON 4
J NORTHWEST -
M HENDERSON 2
D DESERT INN GOLF COURSE 2
A ARDEN -
U WINTERWOOD -
N
J
S
E
U
D
M
A

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 800. AND 900. PST

Figure C-13.



MEASURED CO CONCENTRATION

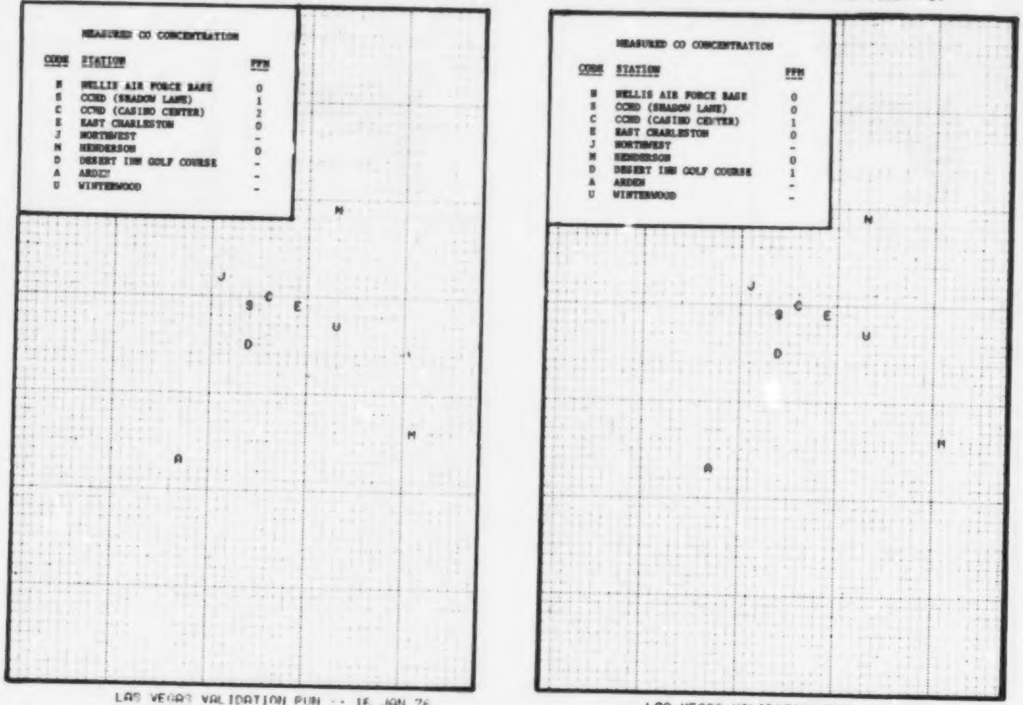
CODE	STATION	PPM
N	WELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	5
F	EAST CHARLESTON	2
J	NORTHWEST	-
M	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 900. AND 1000. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	WELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	3
E	EAST CHARLESTON	0
J	NORTHWEST	-
M	HENDERSON	0
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1000. AND 1100. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	WELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	2
E	EAST CHARLESTON	0
J	NORTHWEST	-
N	HENDERSON	0
D	DESERT INN GOLF COURSE	-
A	ARDEN	-
U	WINTERWOOD	-

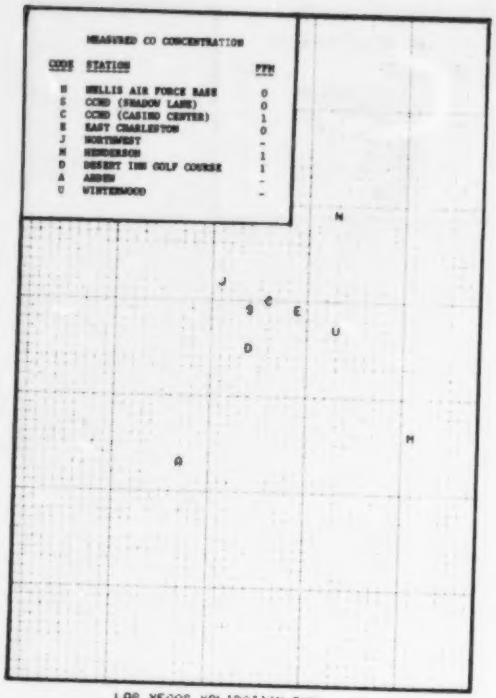
LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1100. AND 1200. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	WELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	0
C	CCHD (CASINO CENTER)	1
E	EAST CHARLESTON	0
J	NORTHWEST	-
M	HENDERSON	0
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1200. AND 1300. PST

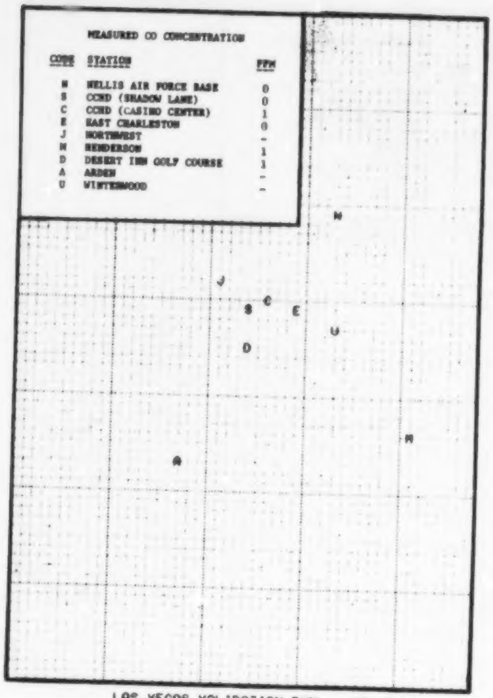
Figure C-14.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	0
C	CCHD (CASINO CENTER)	1
E	EAST CHARLESTON	0
J	NORTHWEST	-
M	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

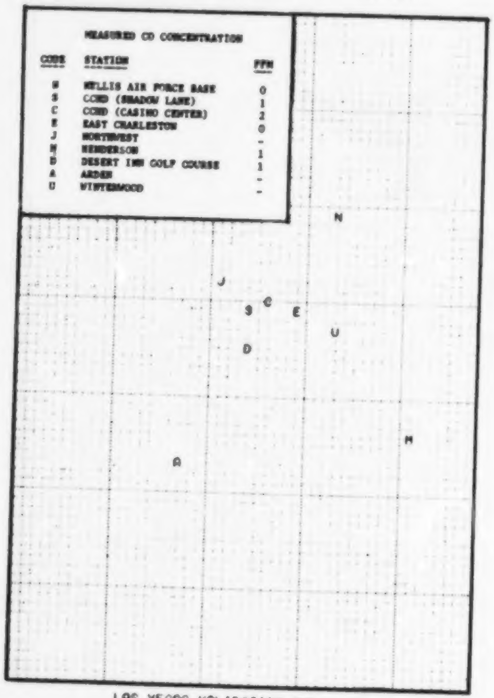
LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1300. AND 1400. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	0
C	CCHD (CASINO CENTER)	1
E	EAST CHARLESTON	0
J	NORTHWEST	-
M	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

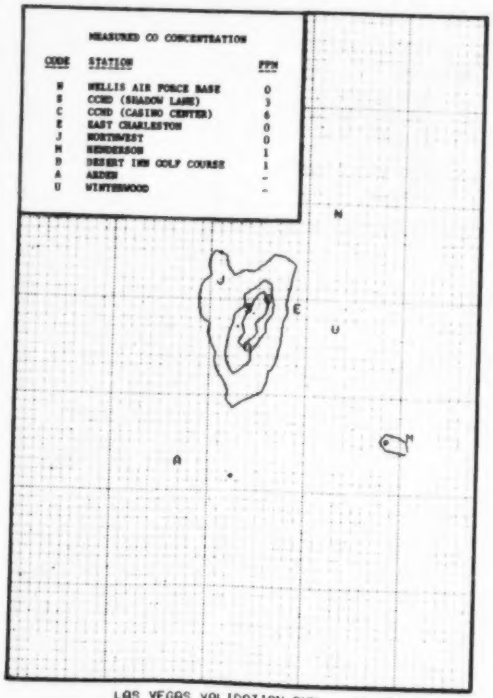
LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1400. AND 1500. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	2
E	EAST CHARLESTON	0
J	NORTHWEST	-
M	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1500. AND 1600. PST

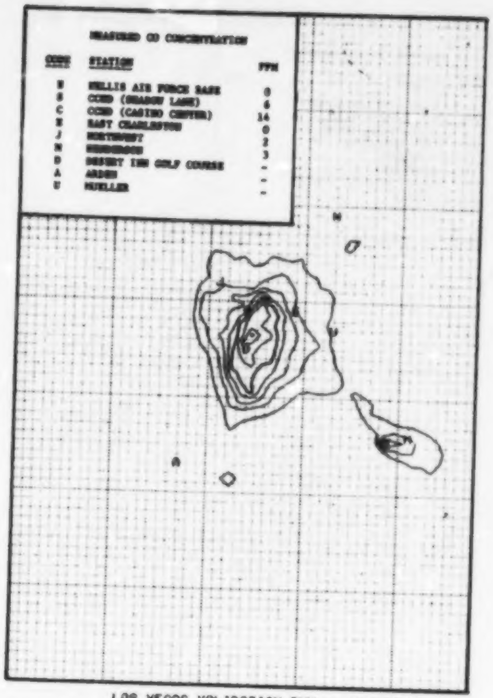


MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	6
E	EAST CHARLESTON	0
J	NORTHWEST	0
M	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	-
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1600. AND 1700. PST

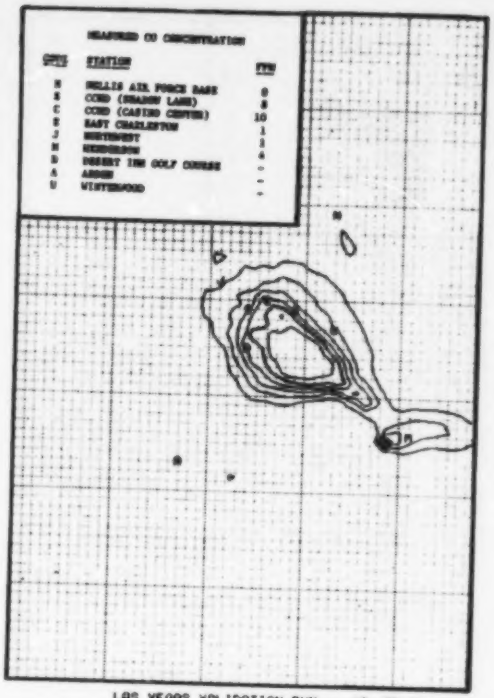
Figure C-15.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	6
C	CCHD (CASINO CENTER)	14
E	EAST CHARLESTON	0
J	NORTHWEST	2
H	HENDERSON	3
D	DESERT INN GOLF COURSE	-
A	ARDEN	-
U	MUELLER	-

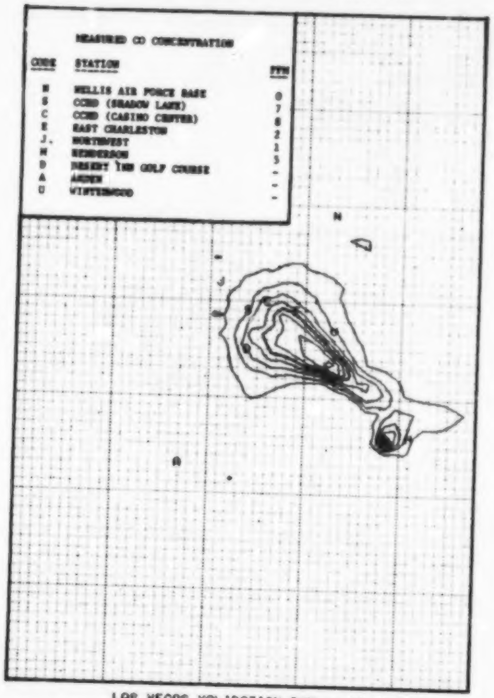
LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1700. AND 1800. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	10
E	EAST CHARLESTON	1
J	NORTHWEST	1
H	HENDERSON	4
D	DESERT INN GOLF COURSE	-
A	ARDEN	-
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1800. AND 1900. PST

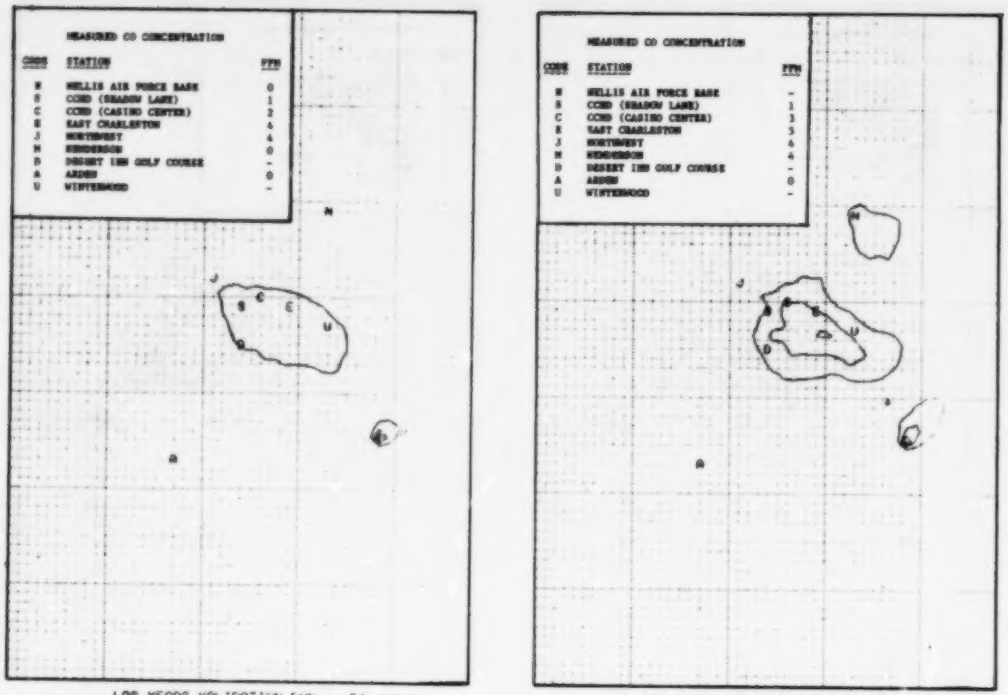


MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	7
C	CCHD (CASINO CENTER)	8
E	EAST CHARLESTON	2
J.	NORTHWEST	1
H	HENDERSON	5
D	DESERT INN GOLF COURSE	-
A	ARDEN	-
U	WINTERWOOD	-

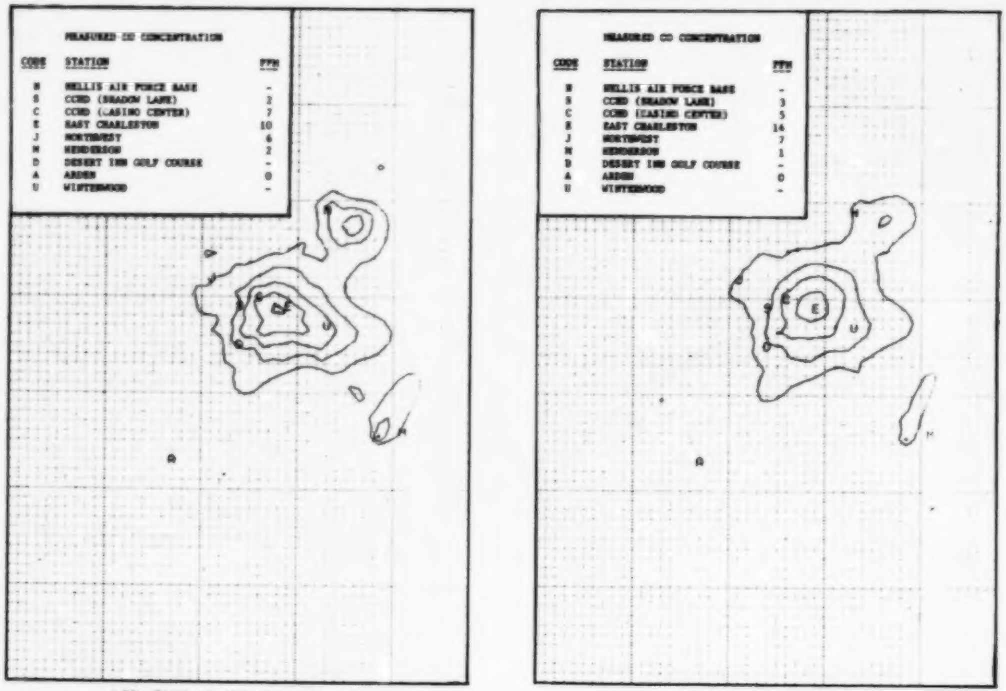
LAS VEGAS VALIDATION RUN -- 16 JAN 76
CO BETWEEN THE HOURS OF 1900. AND 2000. PST

Figure C-16.


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 2
E EAST CHARLESTON 4
J NORTHWEST 4
H HENDERSON 0
D DESERT INN GOLF COURSE -
A ARDEN 0
U WINTERWOOD -
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 3
E EAST CHARLESTON 5
J NORTHWEST 4
H HENDERSON 4
D DESERT INN GOLF COURSE -
A ARDEN 0
U WINTERWOOD -

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 500. AND 600. PST

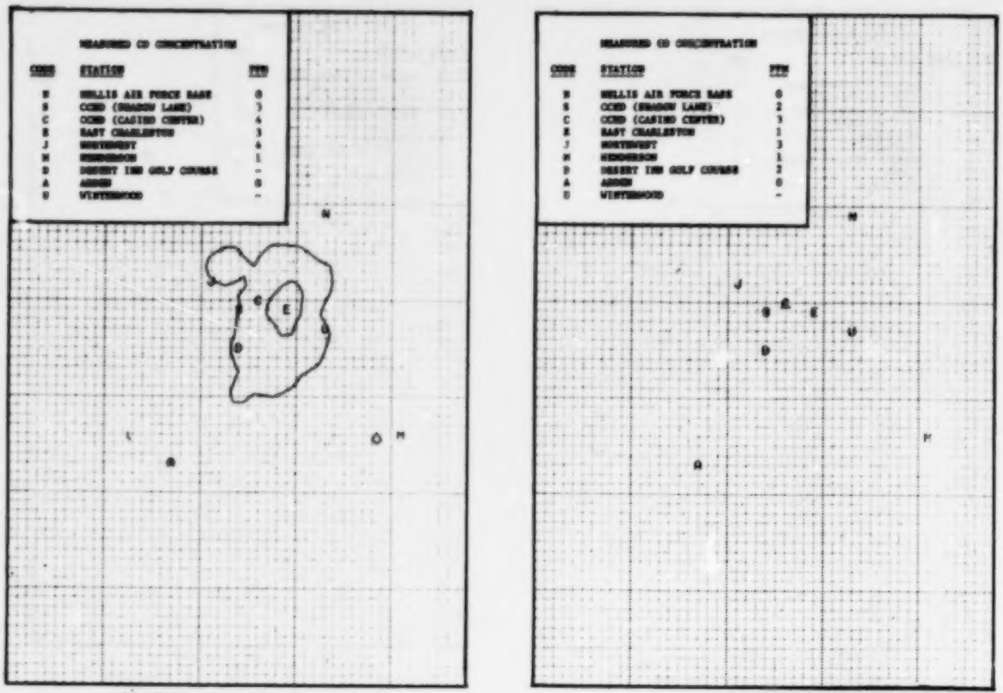
LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 600. AND 700. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 2
C CCHD (CASINO CENTER) 7
E EAST CHARLESTON 10
J NORTHWEST 6
H HENDERSON 2
D DESERT INN GOLF COURSE -
A ARDEN 0
U WINTERWOOD -
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 3
C CCHD (CASINO CENTER) 5
E EAST CHARLESTON 14
J NORTHWEST 7
H HENDERSON 1
D DESERT INN GOLF COURSE -
A ARDEN 0
U WINTERWOOD -

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 700. AND 800. PST

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 800. AND 900. PST

Figure C-17.



MEASURED CO CONCENTRATION

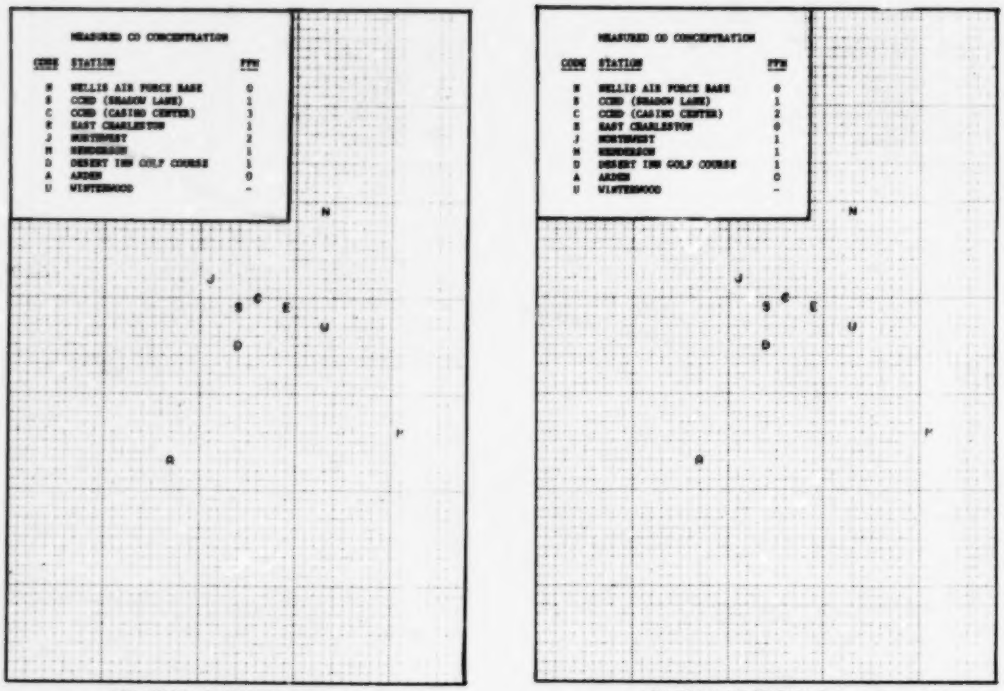
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	4
E	EAST CHARLESTON	3
J	NORTHWEST	4
H	HENDERSON	1
D	DESERT INN GOLF COURSE	-
A	ARDEN	0
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 21 JAN 76
CO BETWEEN THE HOURS OF 900. AND 1000. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	2
C	CCHD (CASINO CENTER)	3
E	EAST CHARLESTON	1
J	NORTHWEST	3
H	HENDERSON	1
D	DESERT INN GOLF COURSE	2
A	ARDEN	0
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 21 JAN 76
CO BETWEEN THE HOURS OF 1000. AND 1100. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	3
E	EAST CHARLESTON	1
J	NORTHWEST	2
H	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	0
U	WINTERWOOD	-

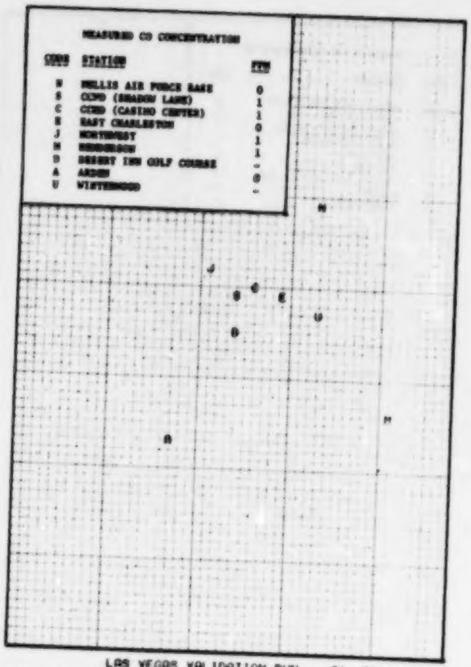
LAS VEGAS VALIDATION RUN -- 21 JAN 76
CO BETWEEN THE HOURS OF 1100. AND 1200. PST

MEASURED CO CONCENTRATION

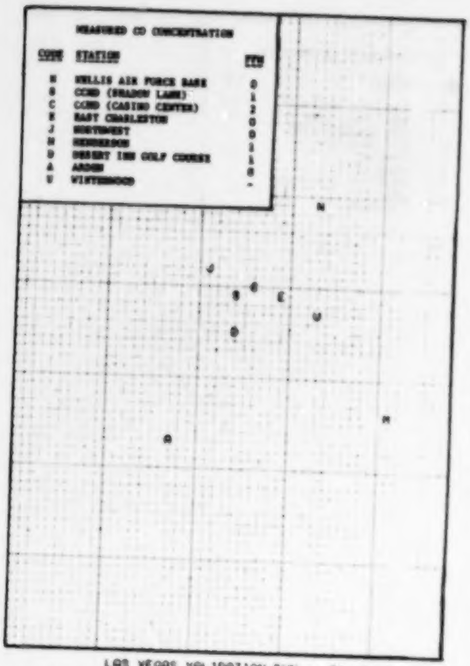
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	2
E	EAST CHARLESTON	0
J	NORTHWEST	1
H	HENDERSON	1
D	DESERT INN GOLF COURSE	1
A	ARDEN	0
U	WINTERWOOD	-

LAS VEGAS VALIDATION RUN -- 21 JAN 76
CO BETWEEN THE HOURS OF 1200. AND 1300. PST

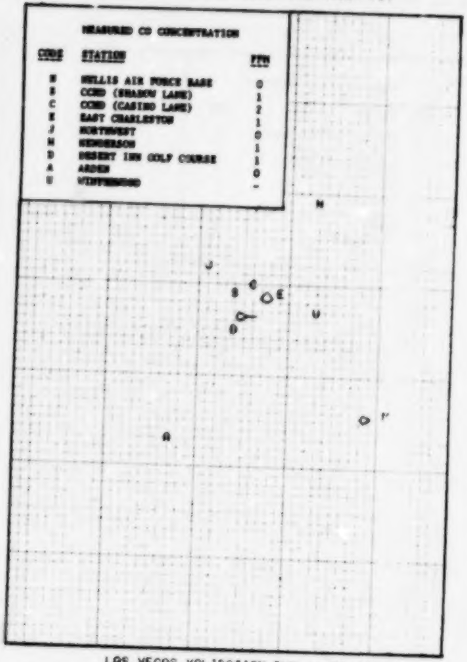
Figure C-18.


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 1
E EAST CHARLESTON 0
J NORTHWEST 1
H HENDERSON 1
D DESERT INN GOLF COURSE -
A ARDEN 0
U WINTERWOOD -
N
J
S
C
E
U
D
A
H

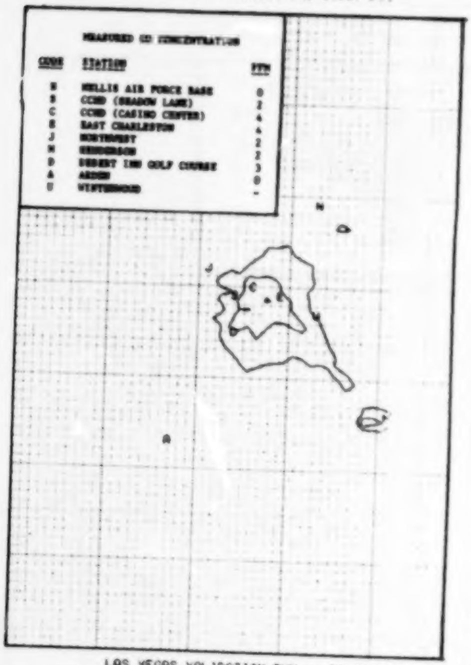
LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1300. AND 1400. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 2
E EAST CHARLESTON 0
J NORTHWEST 0
H HENDERSON 1
D DESERT INN GOLF COURSE 1
A ARDEN 0
U WINTERWOOD -
N
J
S
C
E
U
D
A
H

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1400. AND 1500. PST

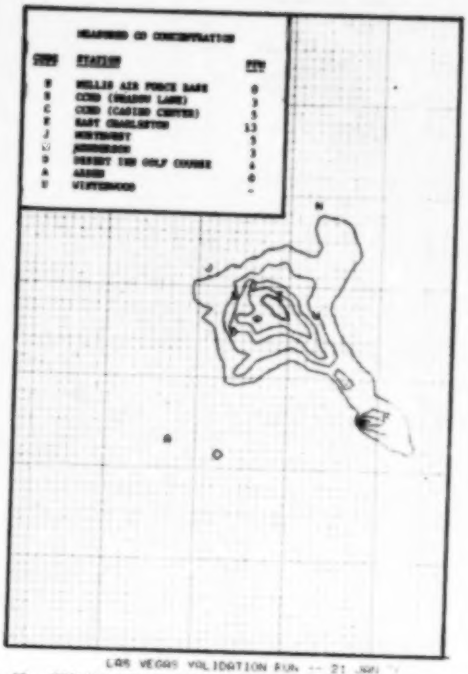

MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO LANE) 2
E EAST CHARLESTON 1
J NORTHWEST 0
H HENDERSON 1
D DESERT INN GOLF COURSE 1
A ARDEN 0
U WINTERWOOD -
N
J
S
C
E
U
D
A
H

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1500. AND 1600. PST

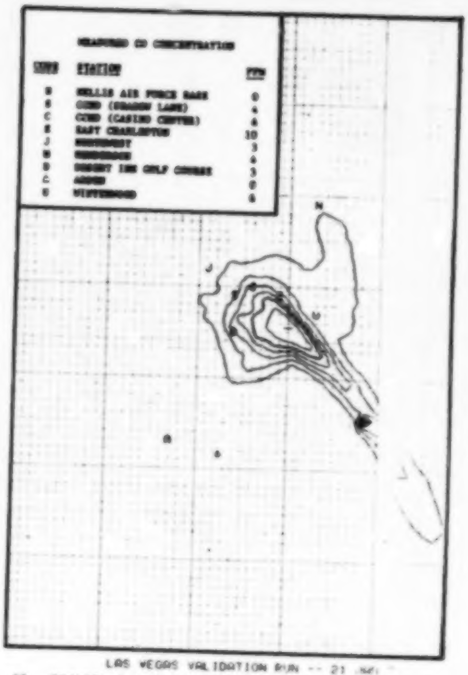

MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 2
C CCHD (CASINO CENTER) 4
E EAST CHARLESTON 4
J NORTHWEST 2
H HENDERSON 2
D DESERT INN GOLF COURSE 3
A ARDEN 0
U WINTERWOOD -
N
J
C
A

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1600. AND 1700. PST

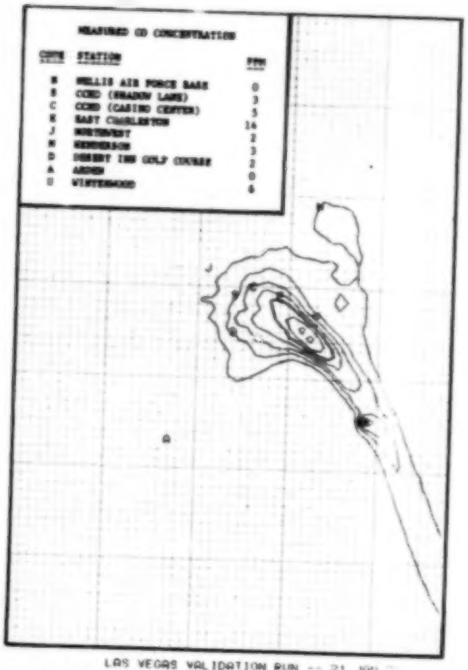
Figure C-19.


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 3
C CCHD (CASINO CENTER) 5
E EAST CHARLESTON 13
J NORTHWEST 5
H HENDERSON 3
D DESERT INN GOLF COURSE 4
A ARDEN 0
W WINTERWOOD -
N
J

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1700. AND 1800. PST

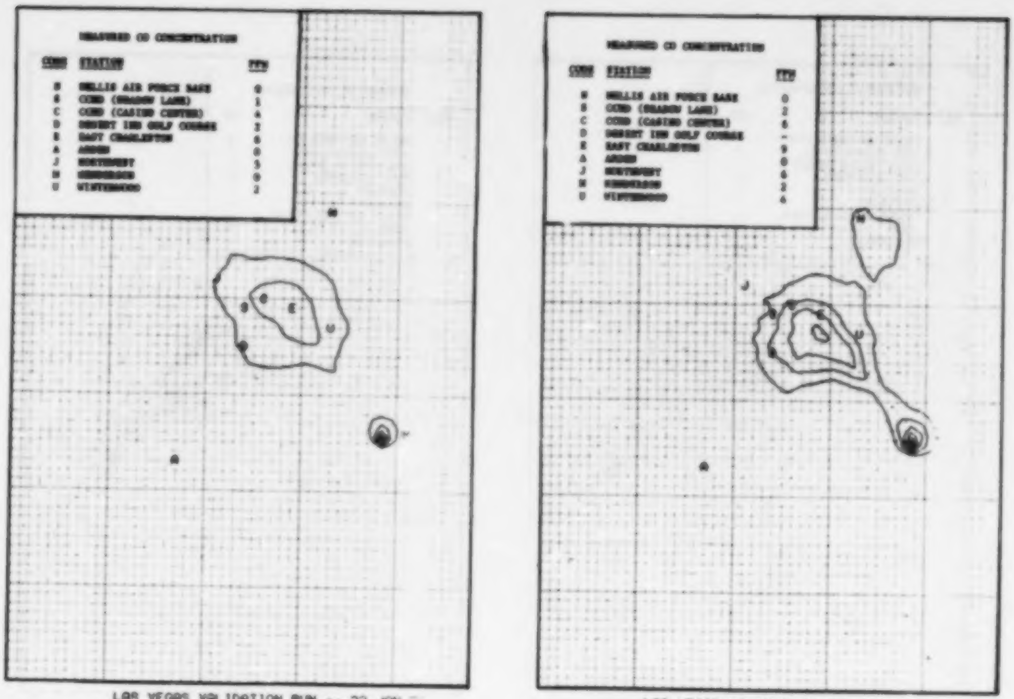

MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 4
C CCHD (CASINO CENTER) 4
E EAST CHARLESTON 10
J NORTHWEST 3
H HENDERSON 4
D DESERT INN GOLF COURSE 3
A ARDEN 0
W WINTERWOOD 6
N
J

LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1800. AND 1900. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 3
C CCHD (CASINO CENTER) 5
E EAST CHARLESTON 14
J NORTHWEST 2
H HENDERSON 3
D DESERT INN GOLF COURSE 2
A ARDEN 0
W WINTERWOOD 6
J

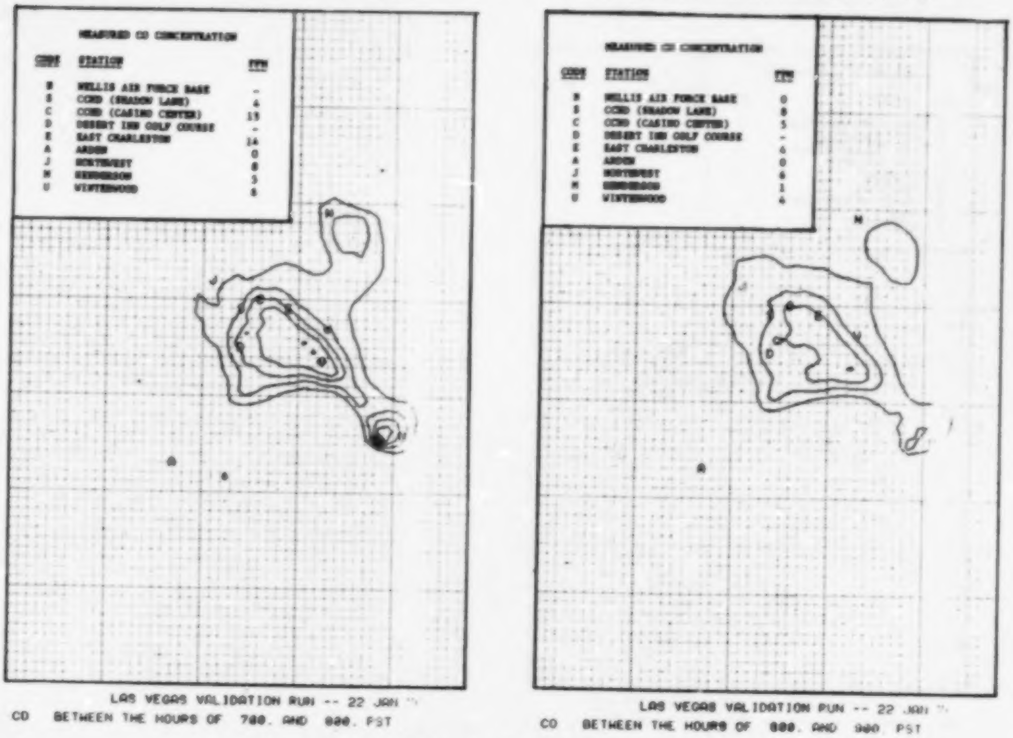
LAS VEGAS VALIDATION RUN -- 21 JAN
CO BETWEEN THE HOURS OF 1900. AND 2000. PST

Figure C-20.


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 1
C CCHD (CASINO CENTER) 4
D DESERT INN GOLF COURSE 2
E EAST CHARLESTON 6
A ARDEN 0
J NORTHWEST 5
H HENDERSON 0
W WINTERWOOD 2
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 2
C CCHD (CASINO CENTER) 6
D DESERT INN GOLF COURSE -
E EAST CHARLESTON 9
A ARDEN 0
J NORTHWEST 6
H HENDERSON 2
W WINTERWOOD 4

LAS VEGAS VALIDATION RUN -- 22 JAN
CO BETWEEN THE HOURS OF 500. AND 600. PST

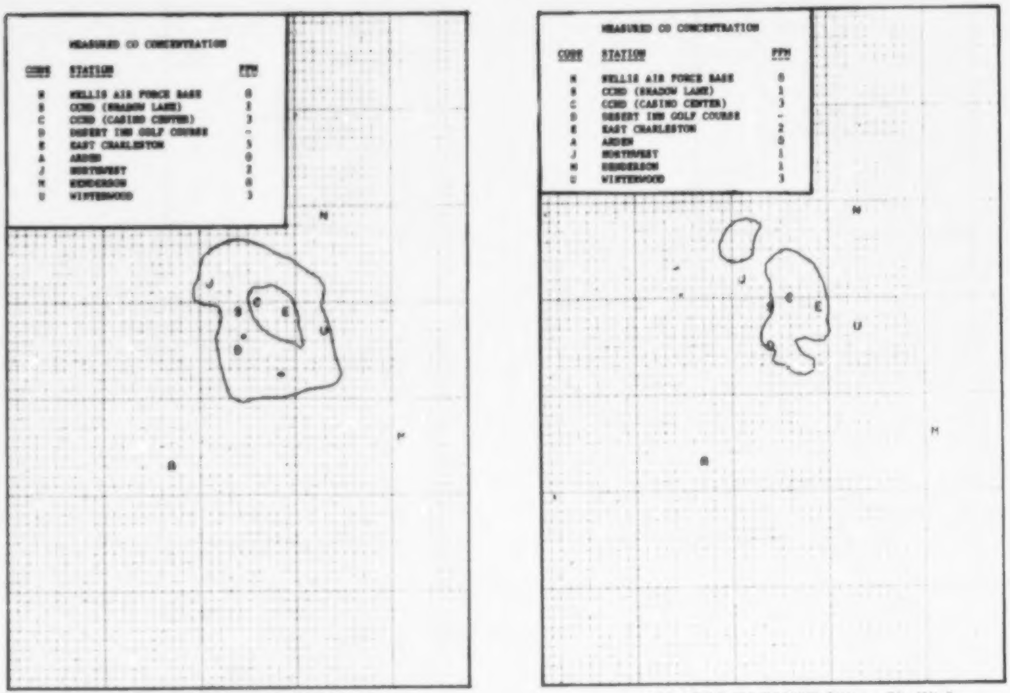
LAS VEGAS VALIDATION RUN -- 22 JAN
CO BETWEEN THE HOURS OF 600. AND 700. PST


MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE -
S CCHD (SHADOW LANE) 4
C CCHD (CASINO CENTER) 13
D DESERT INN GOLF COURSE -
E EAST CHARLESTON 14
A ARDEN 0
J NORTHWEST 8
H HENDERSON 3
W WINTERWOOD 8
MEASURED CO CONCENTRATION
CODE STATION PPM
N NELLIS AIR FORCE BASE 0
S CCHD (SHADOW LANE) 8
C CCHD (CASINO CENTER) 5
D DESERT INN GOLF COURSE -
E EAST CHARLESTON 6
A ARDEN 0
J NORTHWEST 6
H HENDERSON 1
W WINTERWOOD 4

LAS VEGAS VALIDATION RUN -- 22 JAN
CO BETWEEN THE HOURS OF 700. AND 800. PST

LAS VEGAS VALIDATION RUN -- 22 JAN
CO BETWEEN THE HOURS OF 800. AND 900. PST

Figure C-21.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	3
C	CCHD (CASINO CENTER)	3
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	5
A	ARDEN	0
J	NORTHWEST	2
H	HENDERSON	0
U	WINTERWOOD	3

LAS VEGAS VALIDATION RUN -- 22 JAN

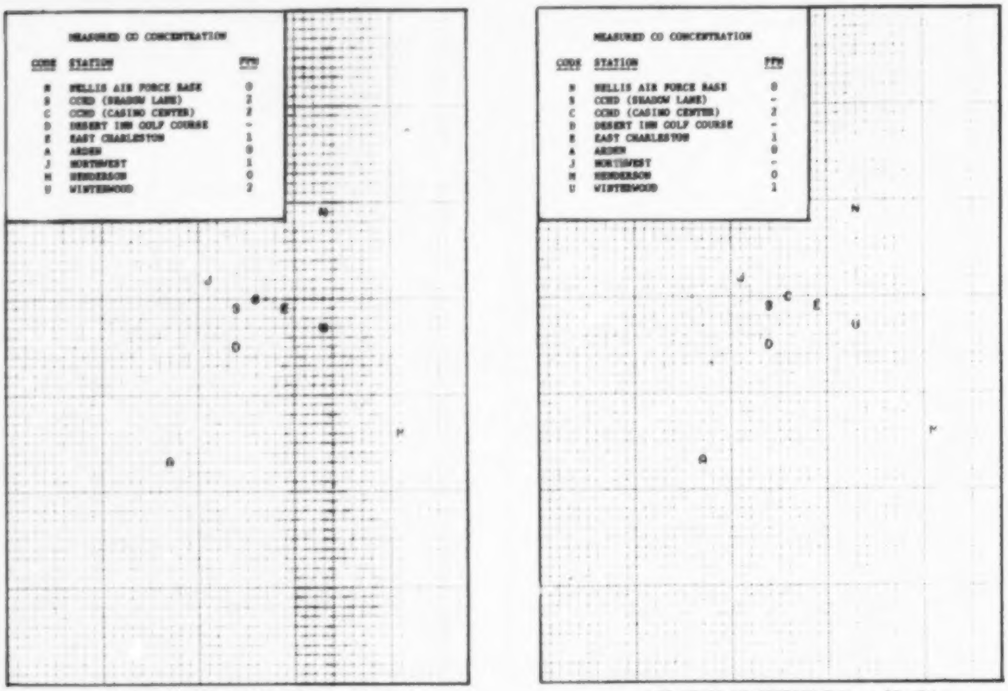
CO BETWEEN THE HOURS OF 900. AND 1000. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	3
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	2
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	1
U	WINTERWOOD	3

LAS VEGAS VALIDATION RUN -- 22 JAN

CO BETWEEN THE HOURS OF 1000. AND 1100. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	2
C	CCHD (CASINO CENTER)	2
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	1
H	HENDERSON	0
U	WINTERWOOD	2

LAS VEGAS VALIDATION RUN — 22 JAN

CO BETWEEN THE HOURS OF 1100. AND 1200. PST

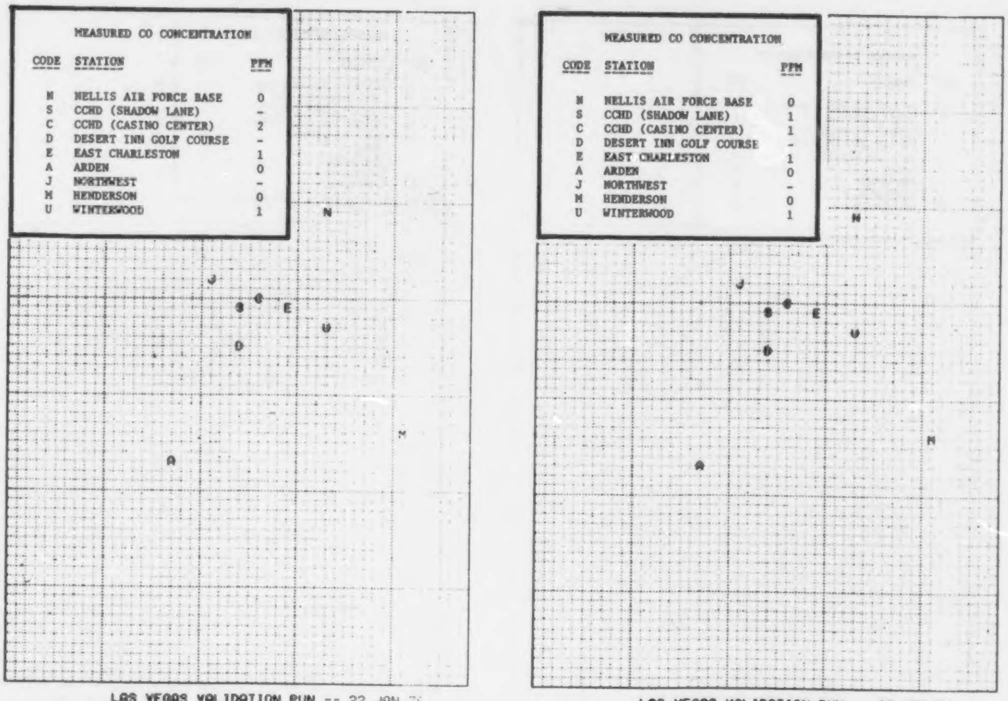
MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	-
C	CCHD (CASINO CENTER)	2
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	0
U	WINTERWOOD	1

LAS VEGAS VALIDATION RUN -- 22 JAN

CO BETWEEN THE HOURS OF 1200. AND 1300. PST

Figure C-22.



MEASURED CO CONCENTRATION

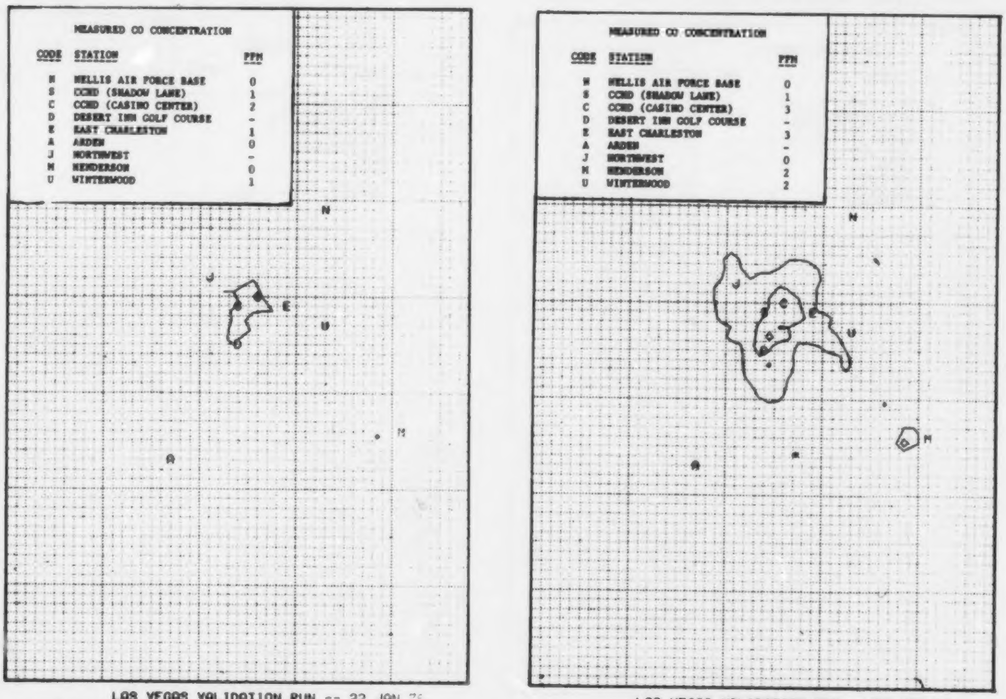
CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	-
C	CCHD (CASINO CENTER)	2
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
M	HENDERSON	0
U	WINTERWOOD	1

LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1300. AND 1400. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	1
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
M	HENDERSON	0
U	WINTERWOOD	1

LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1400. AND 1500. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	2
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	1
A	ARDEN	0
J	NORTHWEST	-
M	HENDERSON	0
U	WINTERWOOD	1

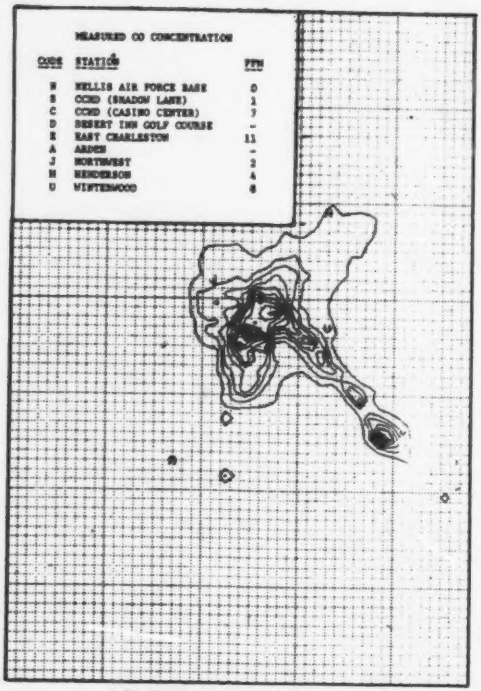
LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1500. AND 1600. PST

MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	3
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	3
A	ARDEN	-
J	NORTHWEST	0
M	HENDERSON	2
U	WINTERWOOD	2

LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1600. AND 1700 PST

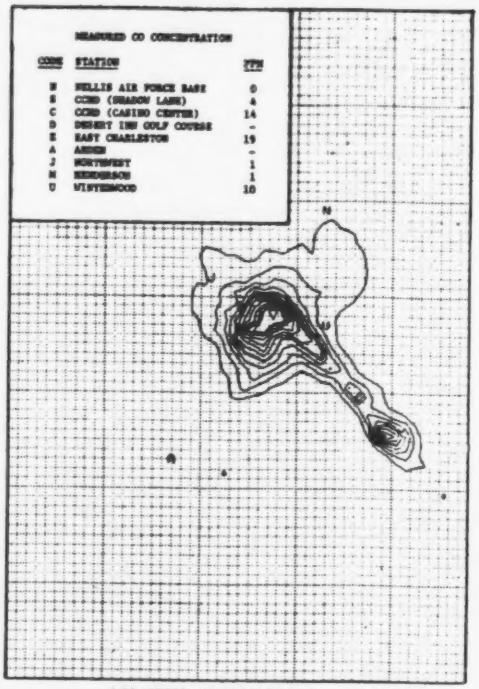
Figure C-23.



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	1
C	CCHD (CASINO CENTER)	7
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	11
A	ARDEN	-
J	NORTHWEST	2
H	HENDERSON	4
U	WINTERWOOD	8

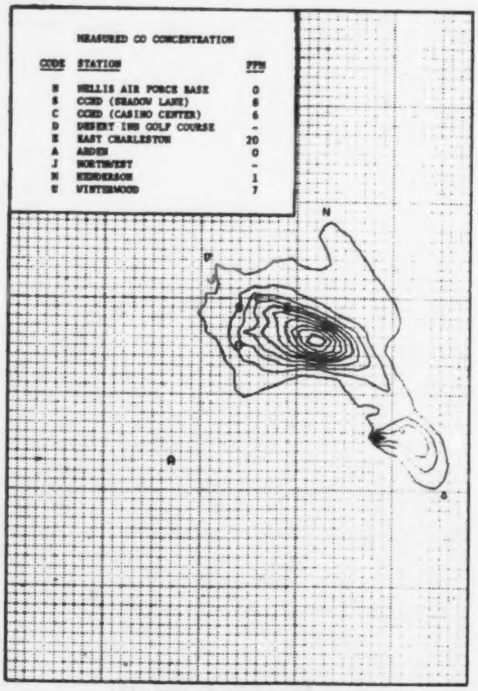
LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1700. AND 1800. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	4
C	CCHD (CASINO CENTER)	14
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	19
A	ARDEN	-
J	NORTHWEST	1
H	HENDERSON	1
U	WINTERWOOD	10

LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1800. AND 1900. PST



MEASURED CO CONCENTRATION

CODE	STATION	PPM
N	NELLIS AIR FORCE BASE	0
S	CCHD (SHADOW LANE)	8
C	CCHD (CASINO CENTER)	6
D	DESERT INN GOLF COURSE	-
E	EAST CHARLESTON	20
A	ARDEN	0
J	NORTHWEST	-
H	HENDERSON	1
U	WINTERWOOD	7

LAS VEGAS VALIDATION RUN -- 22 JAN 76
CO BETWEEN THE HOURS OF 1900. AND 2000. PST

Figure C-24.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978--684-050/2039